Lexical Segmentation and Word Recognition in Fluent Aphasia

Mary Louise Kelly

I declare that the production of this thesis and the work reported herein was carried out by me except where otherwise stated.

Signed [illegible]

Date [illegible]

PhD

University of Edinburgh

1993

I declare that the production of this thesis and the work reported herein were carried out by me except where otherwise stated.

Signed..

Date........March 1994................

Acknowledgements

Now that I have at last completed this thesis and declared that the work in it is all mine, I realise that so much is due to the input of many other people. I cannot hope to acknowledge them all in name.

My first debt is to Mary and Tom Kelly; my parents. Thank you for all the support and encouragement you have given me and interest you have taken in the things I have chosen to do. Deserving equal mention for being an equally important bunch of people are our Chris, Joanne and Kathleen.

The preparation of the thesis has required the involvement of numerous people. First I would like to thank those responsible for providing both the control and pathological data. The collection of the pathological data relied on the co-operation of many speech therapists in Lothian Region who allowed me to visit their clinics and referred appropriate subjects to me. I am grateful. An even bigger debt is owed to the subjects themselves. Many of them are frustrated with their linguistic abilities but all of them showed me patience in my attempts at investigating their conditions. I hope they realise the respect they have commanded. Thank you, also, to the non-aphasic people who gave of their time and didn't give up when the experiments were long.

Then I would like to express my thanks to those giving technical assistance. Thank you to the departmental technical and computing staff for putting up with my, not always successful, attempts at learning new methods of stimuli preparation and data analysis. Without their support I could not have completed this work. For further technical assistance beyond the call of duty, I would like to thank Mike Morony. He patiently helped with awk scripts during the days spent preparing stimuli for these experiments - his help was much appreciated. Robin Lickley, too, has contributed much in the way of solace, help and encouragement as I have tried to master the art of using computers and thinking about psycholinguistics.

Ethel Jack also deserves special thanks. She not only provided her very individual welcome when I first encountered the Edinburgh Linguistics Department, but also gave of her golden voice for the purposes of materials preparation. Like so many other colleagues in the department she has kept me sane. In fact, anyone who has reconstructed me after I have felt the work to be too gruelling, or ever made me laugh, should know I am indebted to them.

The time I've spent doing this work has been under the guidance of many insightful people. I am particularly indebted to Jan McAllister, Alan Kemp and Christine Skinner for starting me off in this project. I hope they feel it has borne some fruit. Ellen Gurman Bard is responsible for any ability I have to understand empirical design and the statistical analysis of data. She is, of course, without blame for any failings in these areas in the thesis. Like many students before me, I am impressed by her ability to cajole you into thinking a little more coherently. She has proved to be an inspirational role model and a source of wise, intellectual, and practical advise in hours of crisis.

After thanking those who started me off, it is tempting to address my next thanks to my supervisor, Richard Shillcock, as 'the person who has tried to finish me off'. This would not, however, convey the gratitude I feel toward him for his unerring encouragement, advice, deadlines, cups of tea, patience and a million hours of discussion about aphasia and language processing. He has taken time to get to know me as well as my work; this undoubtedly has allowed chinks of enjoyment to break into the draining task of finishing this work.

The last word of acknowledgement and dedication of the thesis goes to my best friend, Andy Pitts. Our partnership began almost at the start of this research project and he has shared in every aspect of the thesis since. I could not have hoped to share it with anyone more tolerant, heartening and kind. Thank you Andy, you are marvellous.

Abstract

The current thesis reports a psycholinguistic study of lexical segmentation and word recognition in fluent aphasia.

When listening to normal running speech we must identify individual words from a continuous stream before we can extract a linguistic message from it. Normal listeners are able to resolve the segmentation problem without any noticeable difficulty. In this thesis I consider how fluent aphasic listeners perform the process of lexical segmentation and whether any of their impaired comprehension of spoken language has its provenance in the failure to segment speech normally.

The investigation was composed of a series of 5 experiments which examined the processing of both explicit acoustic and prosodic cues to word juncture and features which affect listeners' segmentation of the speech stream implicitly, through inter-lexical competition of potential word matches.

The data collected show that lexical segmentation of continuous speech is compromised in fluent aphasia. Word hypotheses do not always accrue appropriate activational information from all of the available sources within the time frame in which segmentation problem is normally resolved. The fluent aphasic performance, although quantitatively impaired compared to normal, reflects an underlying normal competence; their processing seldom displays a totally qualitatively different processing profile to normal. They are able to engage frequency, morphological structure, and imageability as modulators of activation. Word class, a feature found to be influential in the normal resolution of segmentation is not used by the fluent aphasic studied. In those cases of occasional failure to adequately resolve segmentation by automatic frequency mediated activation, fluent aphasics invoke the metalinguistic influence of real world plausibility of alternative parses.

Table of Contents

List of Figures

List of Tables

Chapter 1

Introduction

When we listen to normal running speech we must identify individual words in the spoken utterance before we can extract a linguistic message from it. The speech stream does not, however, offer the listener words as discrete entities surrounded by silence. Despite this, normal listeners are able to resolve the problem of segmenting the continuous acoustic stream into words without any noticeable difficulty. In this thesis I consider how fluent aphasic listeners perform this process of lexical segmentation and whether any of their impaired comprehension of spoken language has its provenance in the failure to segment speech normally.

1.1. What is the lexical segmentation problem?

The acoustic signal of which speech is comprised is continuous; unlike written language, which contains spaces to separate individual words, the speech stream does not contain convenient gaps corresponding to word boundaries. Hence, the listener does not receive speech input as isolated, complete and discrete lexical items. Coarticulatory effects, which are the mutual influence exerted by contiguous phonological elements are therefore brought to bear not only on segments within words but are also effective across word boundaries. This makes the relationship between the acoustic signal and the intended lexical segmentation more opaque still. Even read speech does not provide the listener with citation form phonemes or canonical (citation/standard) forms of words. Spontaneous spoken utterances are even less canonical than those of carefully read speech. Indeed, when words are excerpted from recordings of running speech and played in isolation, they are often unrecognizable (Bond, 1976). It would seem, then, that the listener's task of locating word boundaries is not trivial. The quest for the solution of the segmentation problem forms the arena in which this thesis is situated. The focus of the thesis is the consideration of how fluent aphasics, when presented with this stream of underspecified and highly encrypted information, extract a speaker's intended message.

1.1.1. Processes by which listeners accomplish segmentation under normal circumstances

The question of exactly how lexical segmentation is achieved has been approached in three fundamentally different ways. The first was based on the hypothesis that words are recognised sequentially. Models which incorporate sequential word recognition support the notion that the listener knows that it is time to posit the onset of a new word when they have attached the current chunk of acoustic signal to a lexical representation. That is, they segment the speech stream by recognising one word and positing a new onset at the end of the recognised item. (Cole & Jakimik, 1978, Marslen-Wilson and Welsh, 1978). Segmentation is accomplished, therefore, through strict sequential recognition of words. The success of such a strategy requires that words can be completely identified before their offset. The structure of the lexicon makes it unlikely that such a strategy would be workable (McQueen & Cutler, 1992, Frauenfelder, 1991, Luce, 986a). Luce (1986a), for instance, reports that 40% of words are not unique at their offset. This means that the listener can not be sure that they have heard the complete intended word when they are presented with a string like *cat* because the speaker may continue to form a longer lexical item such as *cattle*, or *catalogue*. If listeners were to employ a strictly sequential access strategy, they could not assuredly posit a new onset until well after the end of *cat*. Sequential analysis could not cope efficiently with the degree of phonological overlap between lexical items and could not segment running speech for successful word recognition. Even for words like *trespass* which are lexically unique well before their offset (at *tresp*), the listener would still have to entertain the possibility that the intended message was *trespassing* (Shillcock, 1990). Behavioural data from gating experiments (Bard et al., 1988, Grosjean, 1985) provide evidence supporting this intuition; listeners fail to identify perhaps 20% of words before their offset. It has been argued that top-down syntactic information could constrain the emergence of candidates in such a way that phonologically overlapping words would not be problematic to the listener's decision to segment (Marslen-Wilson, 1987), but, as McQueen et al. (1993) point out, words which do not become unique until after their offset often occur in neutral contexts so reliance on contextual constraints could not be total. In addition, the fact that much normal spontaneous speech is disfluent - it contains hesitations, repetitions and false starts - suggests that a syntactic structure from which to impose such constraints would not always be reliably constructed. This current thesis does not give further independent consideration to sequential recognition.

The second approach expounded in the literature assumes that the processor employs active strategies to locate word boundaries. Numerous studies have suggested that the listener segments the acoustic stream by attending to acoustic and phonetic cues (Lehiste, 1960, Nakatani & Dukes, 1977, Barry, 1981). Models which support such a strategy suggest that the speech stream, despite containing only few silences as cues to word boundaries (around 20% of words may be marked), has regular allophonic variation and junctures. Further they propose that such variation is detectable by listeners and signals lexical boundaries. Other models which support explicit cues to segmentation hypothesise that the prosodic structure of a language triggers lexical access attempts. That is, the listener makes lexical access attempts at parts of the speech stream which have particular prosodic properties. For English, the metrically strong syllables are proposed as such triggers (Norris & Cutler, 1985, Cutler & Norris, 1988).

A third proposal is that, rather than segmentation being a separate prerequisite for lexical access, the two are resolved simultaneously (McClelland & Elman, 1986; Norris, 1993). Supporters of interactionist solutions suggest that the language processor resolves the segmentation of even initially ambiguous signals, through activation of, and competition between, potential lexical matches for the signal without the need for attention to low level cues. Indeed, proponents of some such models (e.g. TRACE, McClelland and Elman, 1986) claim that the acoustic input is often so underspecified or highly contaminated by noise, that a segmentation system which was heavily dependent on the minimally acoustic cues to segmentation would be unreliable. Others

(SHORTLIST, Norris) suggest that inter-word competition is enhanced by the working of some explicit cues for segmentation.

1.1.2. How do aphasics segment the speech stream?

Whether the method by which lexical segmentation is achieved relies on explicit or implicit segmentation mechanisms, it is clear that for normal listeners, the process is accomplished without conscious effort and in a time scale compatible with the speed needed to process spontaneous speech. Little is known, however, of how linguistically impaired listeners accomplish lexical segmentation. There have been no substantial studies to date which deal directly with the issue of segmentation in fluent aphasia. Only indirect evidence has ever been gathered for the facility with which fluent aphasics posit word boundaries or clear up inter-word competition. Before I give an outline of how these phenomena will be addressed in the current thesis, let us consider briefly why the issue of segmentation has no profile in the aphasic literature.

An important reason for this may be that the main thrust of the genre of models most used to describe aphasic language over the past fifteen years (namely the cognitive neuropsychological models; e.g. Morton and Patterson, 1980) has been the description of functional breakdown at the single word level. A natural consequence of studying impairments of lexical access and word recognition problems using isolated words has been that the crucial stage of identifying how the listener knows where to initiate lexical access has been largely ignored. Therapeutic profiling batteries such as PALPA are skewed toward the single word level. They have not addressed the complexities involved in either boundary detection or initiating access from an acoustically continuous stream. Little can be gathered from the traditional assessment of aphasics about how the process proceeds in the damaged brain. Further, the lack of specificity offered by mainstream linguistics as to the process of lexical segmentation in normal listeners has done nothing to encourage the study of the issue in the aphasiological domain.

Because there is a lack of clear consensus on normal lexical segmentation, the experiments conducted as part of this thesis compare the performance of fluent aphasics with that of a non-brain-damaged population to see how both of the subject groups marry all of the available information to engage with a target presented in a speech stream.

1.2. The approach to the segmentation problem adopted in this thesis

The current thesis comprises a psycholinguistic investigation of lexical segmentation in fluent aphasia. Several psycholinguistic frameworks, models, and theories (Cohort Model (Marslen-Wilson and Welsh, 1978, Marslen-Wilson, 1987, Marslen-Wilson, 1990, Marslen-Wilson, 1992); TRACE (McClelland & Elman, 1986), Metrical Segmentation Strategy (Cutler & Norris, 1988); and current connectionist models e.g. (Seidenberg , 1989)) are invoked to elucidate the data yielded by the investigations. The focus is on how explicit cues to word boundary location and linguistic features which affect inter-word competition (segmentation phenomena) are processed by fluent aphasics. The thesis comprises a discussion of aphasic performance: it reports data from carefully controlled laboratory prepared experiments which give an insight into segmentation within the constraints imposed by the real-time demands of conversational interaction.

1.3. Aims of the thesis

The thesis considers whether the problems that fluent aphasics typically have with comprehension of running speech can in any part be explained at the lexical segmentation level - problems in locating word boundaries. It also aims to characterise the perceptual segmentation strategies available to aphasics when processing continuous speech and to establish how these mechanisms are constrained by the complex of impairments to their language processor. I ask whether any of the deficit in comprehension performance is due to fluent aphasics not picking up specific word juncture or word onset cues. I also ask whether the normally functioning components of the word recognition process are hindered due to more disparate disturbances in processing, making the commitment to word boundary allocation problematic. These questions are addressed in a series of experimental investigations in which I compare the performance of normal ageing subjects with fluent aphasic listeners. This allows direct assessment of normal and aphasic processing and facilitates the search for both qualitative and quantitative differences between these two groups.

The thesis does not aim to find a functional component of segmentation comparable to elements of, say, a cognitive neuropsychological model. Rather, it aspires to quantify how the multiple elements of the segmentation task are coped with when part of the perceptual processing system is impaired or functioning below normal capacity.

1.4. The structure of the thesis

Chapter 2 provides an account of the findings in the literature regarding the concepts of activation of, and competition between, lexical hypotheses. This chapter also contains a survey of the literature concerning frequency effects. Frequency is the lexical feature thought to play one of the major roles in determining activation and competition. Further, the frequency effect is pertinent to the majority of the investigations which form the thesis. Other literature, which is pertinent to one or two investigations only, is described alongside the reports of the relevant experiments.

Chapter 3 considers the data theory of the thesis as a whole. It describes the broader methodological considerations entailed in the thesis. This includes the question of the definition of fluent aphasia, the validity of aphasia classification, a defence of the subject paradigms used (single-case or group methods), exploration of issues concerning the type of information captured by the experimental designs and their usefulness as tools for expanding our knowledge about segmentation related processing in aphasia. This chapter also provides a justification for using normal psycholinguistic models to describe aphasic processing, extrapolating issues of normal processing from the collected aphasic data, and inferring details about on-line processing from off-line measurements of performance. As several different experimental techniques are used in the thesis, individual paradigms are justified and explained at an appropriate point within the chapters which report the findings of each investigation.

The next five chapters each report the findings of experimental investigations into lexical processing for segmentation. The first three experimental chapters (**Chapters 4, 5 and 6**) examine the question of how segmentation is achieved by fluent aphasics by examining data collected at the endpoint of the word recognition process - they consider how the aphasics' grasp of the final representation of the segmented stream varies with the manipulation of independent variables. **Chapters 7 and 8** examine the process of segmentation as it unfolds as revealed by on-line measures, in a single fluent aphasic and in normal ageing control subjects.

Chapters 4 and 5 are concerned with the use of explicit cues to segmentation. **Chapter 4** investigates the ability of fluent aphasics and normal ageing subjects to utilise acoustic cues to lexical segmentation and how they integrate the use of these with employment of other features of the lexical hypotheses offered by the speech steam, such as frequency. The use of metrical prosodic cues for segmentation and initiation of lexical access is explored in **Chapter 5**.

Chapters 6, 7 and 8, consider the competition between overlapping candidates for word recognition and how normals and fluent aphasics resolve this competition and segment the signal. **Chapter 6** considers whether morphological structure plays any part in the ease with which the listener identifies a target polysyllable which has embedded monosyllable competitor hypotheses. **Chapter 7** also examines the processing of polysyllabic words. This enquiry reflects upon whether the frequency of hypotheses with coincident onsets (*cure/curious*) alters the ease with which listeners assume that the word they are hearing should not be segmented to leave a monosyllable, but that a polysyllabic parse is being offered by the speech stream. The investigation reported in **Chapter 8** expands upon the previous investigation by introducing the variable of word class of the monosyllable hypothesis (*in/enough* versus *gin/ginger*). Again the chief objective is to examine the effect of the independent variables on the listeners decision to segment the signal at the point intended by the speaker - to abandon the possible monosyllable parse and give a polysyllabic segmentation.

The final chapter, (**Chapter 9**), examines the findings from each of the experimental investigations. In it I explore the pattern of processing which emerges from the data for the fluent aphasics studied, and compare it with the normal performance data. I conclude by considering what this implies about the way fluent aphasics extract meaning from spoken language.

Chapter 2
Literature Review

The investigation into segmentation which is described in this dissertation draws from many literature sources; both aphasic and mainstream psycholinguistic research have provided the background theory to the work. Numerous traditions of processing are alluded to throughout the thesis and are called upon to provide a framework for the experimental findings reported. The five experimental investigations undertaken require the exposition of different bodies of literature. Various elements of the literature are appropriate to only one or two of the investigations: the review of such work is situated at the beginning of the appropriate chapters. The work reviewed in this chapter is relevant to the models and mechanisms of the processing involved in segmentation of the speech stream.

The initial section of the chapter acknowledges the importance of the frequency effect in the study of the processing models referred to in the thesis. The reason for choosing to explore this issue in detail at the beginning of the dissertation are threefold. First, the frequency effect plays an important role in both the normal and aphasic processing of the segmentation phenomena explored in the majority of the experiments in the thesis; exploring the issues here avoids repetition. Second, it allows the exploration of the fundamental findings and assumptions regarding the role of frequency of lexical candidates in word recognition from the point of view of various psycholinguistic models of processing. Third, it acts as a medium through which to introduce the working definitions of the concepts discussed in the thesis. The next section expands the exploration of the mechanisms of activation and competition. This provides the background to the way the processes involved in segmentation are conceptualised in psycholinguistic frameworks and examines how these processes fit into the models' architectures.

2.1. The frequency effect.

Frequency is one of the most robust lexical features implicated in competition for word recognition. In this section I will present some of the current findings on the frequency effect and consider its potency relevant to other segmentation phenomena in an attempt to establish which lexical features influence word boundary allocation in auditory word recognition. Finally I will review work on the functioning of the frequency effect in aphasia.

2.1.1. Frequency values.

Each word can be assigned a frequency value which refers to the prevalence of that word's use. Frequency is generally calculated from studies of the occurrence of a given word per agreed size of text or transcribed speech. The most commonly cited frequency database records the total occurrence of a given word per so many million words of text and number of texts in which that word occurs (Francis & Kucera, 1982)[1] There are no widely available satisfactory frequency lists compiled from spoken language corpora[2]. The words speakers produce most routinely, necessarily form the set of words which are most often heard by listeners. It is intuitively appealing to predict that these words would be processed differently (in qualitative or quantitative terms) from those with lower relative incidences; the literature indicates that such an intuition is well founded.

2.1.2. Characteristics of the frequency effect.

It has long been established that a word's frequency influences the way it is processed. Extensive research has borne out early findings that subjects respond more rapidly and more accurately to high frequency words than they do to rarer ones. In mainstream psycholinguistic literature the frequency effect is reported to be robust for both auditory

---

[1]This is the word frequency measure employed throughout this thesis.

[2]The Celex database, which is a spoken language corpus, is now more widely available than was the case when the work on this thesis began. For the sake of continuity the use the Francis and Kucera database was retained as the frequency count tool.

(Marslen-Wilson, 1990) and visual (Segui and Grainger, 1990, Andrews, 1992) modalities and across a number of processing tasks such as naming (Forster & Chambers, 1973), lexical decision, (Whaley, 1978, Frederiksen & Kroll, 1976), classification of a word into a specific semantic category (Monsell, 1985) and priming (Segui & Grainger, 1990).

The aphasic literature typically states that aphasic listeners find more recurrent lexical items easier to produce and recognise (Schuell et al., 1961). Again, the frequency effect is apparent in various linguistic tasks such as confrontation naming (Carlew, 1971(reported in (Lesser, 1978)) word retrieval (Lesser, 1978) and phoneme monitoring (Bond, 1971). The strength or even presence of the frequency effect is not, however, always uniform across aphasic type. There is also much contradiction within the literature. Lesser (1978) claims that in word meaning retrieval, the frequency effect is stronger in non-fluent aphasics than fluent aphasics in tasks such as word meaning retrieval. Bradley et al. (1980) suggested that in lexical decision, fluent aphasics show normal frequency sensitivity (that is, show frequency effects only in open-class words) while non-fluent listeners show frequency effects for open- and closed-class words. This leads Bradley et al. to propose the existence of two lexical access routes; one, frequency sensitive, generally used in normal processing, and a second, non-frequency sensitive path, relied upon by people with certain processing impairments.

The existence of novel, post-morbid processing paths or components is not a concept parsimonious with most models of speech recognition, so defence of such a proposal needs to be vigorous. There have been no successful replications of Bradley et al.'s results; attempts to replicate the phenomenon have not been able to fully support the original findings (Segui et al., 1982, Gordon & Caramazza, 1982, Gordon, 1983, Segui et al., 1987). A likely explanation for Bradley's contradictory results is that the closed class items were of unrepresentatively high frequency. Very high frequency words often fail to show a frequency effect due to a floor effect in particular in closed class words. Indeed, in the work of Segui et al. (1987) no frequency effect was found for very high frequency of either open or closed class. The issue of frequency effects of open- versus closed-class words for normal and aphasic subjects is taken up more fully in Chapter 8.

2.1.3. Locus of the frequency effect

The general outline of the frequency effect is not disputed: the idea that frequently heard and used words are easier to process is appealing and is backed up by much behavioural data. More contentious, however, are issues regarding the temporal locus of the frequency effect in word recognition, the list of linguistic activities in which it operates, and the way in which it interacts with other properties of words in the lexicon to influence perception. Locating the frequency effect allows us to determine more precisely how the properties of a word affects its recognition. First it helps identify the points at which frequency affects the identification of input; whether it is influential in biasing the emergence of hypotheses or favouring them once they are activated and whether its influence extends to the post-access phase in tasks such as naming. Second it allows us to consider which parts of linguistics tasks, both natural and experimental, are affected by lexical frequency. Third, it is a basis on which to evaluate the validity of theoretical models of processing by considering their ability to handle the frequency effect data within their framework. Let us consider the question of whether a word's frequency is relevant after lexical access (for instance in the post-access phase of naming) or if it is <u>only</u> of consequence pre-lexically and that it is nullified once a word has been recognised.

2.1.4. Source of Evidence

The search for the locus of the word frequency effect is generally conducted through observation of subject performance in different linguistic tasks. Such experimentation typically enquires whether or not variation in listeners' performance can be ascribed to an effect of word frequency, and if it can, at which point in the process does such an effect operate. Much of the work has centered on defining the role played by frequency in lexical access. Two experimental paradigms which claim to require lexical access for their functioning are lexical decision (LDT) and word naming.

2.1.4.1. Lexical decision tasks

Lexical decision tasks (LDT) require the listener to decided whether a presented string is a word or non-word. It is assumed that lexical decision responses can only be given after a lexical access attempt has been made regardless of whether that attempt proves successful (in the cases when the string corresponds to a real word) or unsuccessful (when the string is a nonsense item). In other words, the LDT response is necessarily a post-access one. The frequency effect is strong in the LDT; frequent items are recognised more rapidly than rare ones (Forster & Chambers, 1973). As the LDT is assumed to necessitate lexical access, such data has led many researchers to conclude that the frequency effect operates at the lexical access level (Frederiksen & Kroll, 1976, Besner & McCann, 1987, Paap et al., 1987). Furthermore, the magnitude of the frequency effect displayed in LDT has engendered great (though not universal) confidence in the task as a sensitive barometer of the role of word frequency. Andrews (1989) proposes that frequency exerts its effect in two ways in word recognition; in that it is sensitive to neighbourhood size and secondly that it is sensitive to response requirements (The response requirements of the lexical decision task being word/nonword discrimination). Nonwords or low frequency words, especially in small neighbourhoods show exaggerated frequency effects in lexical decision because they need double checking.

2.1.4.2. Naming

Investigators using the naming paradigm also report a frequency effect; more frequent words are named faster than rarer ones (Frederiksen & Kroll, 1976, Forster & Chambers, 1973). Generally, however the effect is reported to be smaller than that found in the LDT (Andrews, 1989). Explanations for this are typically of two types; that LDT is a more direct and therefore more accurate reflector of lexical access than naming; or that naming does not necessarily contain a lexical access stage and therefore the frequency effects exhibited reflect the effect of frequency on two different processes at possibly two different loci in the processor.

The difference in size of effect presented by these two paradigms begs the question as to which should be considered the more reliable index of frequency. Paap et al. (1987) claim that the attenuated frequency effect demonstrated in naming tasks reflects the involvement of other non-lexical processes: the complexity of naming thus renders it too opaque for the job of revealing the frequency effect. Chumbley and Balota (1984) suggest that naming is a better indicator of frequency effects. They claim that the greater frequency effect in LDTs is a function of task specific features rather than action of the frequency effect *per se* . They also note that lexical decision data do not allow the frequency effect to be located post- as opposed to pre-lexical access. In addition they argue that this word/nonword, decision process has little to do with lexical access and that a task more reflective of natural word recognition is word naming.

Balota and Chumbley suggested that the immediate naming technique is still somewhat problematic. Lexical access typically takes 100-300ms to complete (Rayner, 1977 (reported in Balota and Chumbley, 1985)); immediate naming does not, therefore, allow sufficient time to complete lexical access. By forcing subjects to wait a minimum of 300ms, any effect of frequency can be claimed to have operated post-access. Several researchers (Balota & Chumbley, 1985, Forster & Chambers, 1973, Monsell et al., 1989) suggested that the locus of the frequency effect could best be found by comparing immediate with delayed naming performances. They argue that if no effect is found in the delay condition, but is found in immediate naming, the locus of the frequency effect can be situated in the lexical access stage of naming.

Balota and Chumbley (1985) conducted a series of experiments to this end using a multiple delay methodology (subjects respond after delays of 0, 150, 400 650, 900, 1150 and 4500 ms). They found a frequency effect in delay conditions but report that it gradually diminished with the increasing time lapse. They concluded that frequency plays its strongest role in the early stages of word recognition but that it remains effectual in post-access processes. These results have been criticised (Seidenberg , 1989a) on the grounds that experimental data collected by Balota and Chumbley, reflect a confound between frequency and ease of articulation. An attempt to disconfound the results was made by McRae et al. (1990) using rhymed and homphonous pairs of stimuli. In their adaptation of Balota and Chumbley's paradigm individual subject's delays were computed using each subject's pre-test baseline response times. The baseline response times were estimated from the subjects' mean naming times of a set of low frequency words. McRae found that many of their subjects' baseline R.T.s were below the threshold for response intervals used by Balota and Chumbly. McRae claims that this invalidates Balota and Chumbley's claim that their paradigm had captured post-access processing responses because a sizeable number of the responses were made before the normal time taken to access rare words in the lexicon.

The materials used by McRae et al. were linguistically sophisticated; words for identification were paired, one member of the pair was high the other low frequency. Members of the pairs were either; homophones, *main-mane*; rhymes, *cold-fold*; or word/non-word pseudohomophones *scam-skam*. The pairs were presented in the multiple delay method. As the materials would require equal articulatory assembly, any difference would be due to frequency effect. If no difference in naming was found, Balota and Chumbley's data could be attributed to ease of articulation differences rather than frequency.

With homophonous stimuli, the frequency effect was only strongly significant in immediate naming. A small frequency effect in the short delay was attributed to insufficient time to assemble the lowest frequency words. The rhyme stimuli showed no effect of frequency. The pseudohomophone condition exhibited a strong frequency effect in immediate naming. The short delay condition yielded a significant effect albeit smaller than in the homophone condition, while the long delay condition showed a non-significant effect. Pronunciation difficulty was again implicated; the non-words (i.e. low frequency items) had more difficult intrinsic pronunciations than the frequent words. A further experiment using even longer baselines showed little or no effect of frequency in either of the delay conditions. This final finding suggests that the difference in the long delay condition for pseudohomophones was a function of the production features of the items rather than one of frequency; the frequency effect had disappeared.

The frequency effect was found to be proportional to the time allotted before the response signal was given. The longer the delay, the less the frequency effect is felt. The frequency effects did persist, however, after the 100-300msc band which is the time typically required for lexical access, implying that the frequency effect is operational immediately post lexical access, but not in the later stages of naming.

Other investigators claim that the effects of word frequency cannot be located at specific points of the word recognition process but that they are distributed throughout. Monsell et al. (1989) experimentally tested their claim that word frequency effects were not restricted to the pre- or immediately post-lexical access loci often reported by others. Frequency effects were found for printed word semantic and syntactic categorisation as well as lexical decision. They also claimed to have found support for the notion that the previously reported smaller frequency effect in naming compared with lexical decision was due to sound to spelling correspondences rather than the task *per se*. The frequency effect was large in naming when the targets were stress final words with unpredictable stress patterns. For stress initial words, the effect was small.

2.1.4.3. Gating

Gating experiments have been used to illustrate the role of word frequency at pre-recognition stages of spoken word identification. In the gating technique, words are presented in small fragments from the word onset in increasingly large fragments. The initial presentation consists of a set size of fragment (typically 50msc), the size of each successive presentation being an increasingly large multiple of the first (e.g. 100msc, 150msc, ...). Grosjean (1980), showed that when words are gated and presented in isolation, frequent words are identified at earlier gates than rare words; that is less word onset information is required to identify high frequency words than low frequency items. Using Dutch materials Tyler (1984) found that, at early gates, listeners made many more high frequency guesses as to target identity than low frequency guesses, even if the target was rare. The bias disappeared in later gates. This suggests the frequency bias is strongest in ambiguous conditions. Wayland et al. (1989) also tested the relationship of target word frequency and the likelihood of word identification at pre-recognition points. They report a non-significant frequency effect but imply that the reason for low frequency guesses at early gates was because of the cohort size at these points. Gating investigations suggest that the frequency effect is present at a pre-recognition stage of word identification.

2.1.4.4. Priming

Priming investigations entail visually presenting a subject with a (prime) word related to the target word which they are asked to identify. Priming data show a transient effect of frequency: for early probes, presented prior to the target word being uniquely acoustically specified, the effect of the prime is larger for high frequency targets than low frequency targets. For instance, the word CAPTAIN is more frequent than its close competitor CAPTIVE. If a prime is presented early in the presentation of these items (eg at /t/, when they are not uniquely specified) the word SHIP (related to CAPTAIN) shows more priming than the word GUARD. When probes are presented at the end of the words, each prime has equal effect (Zwitserlood, 1989, Marslen-Wilson, 1987). These results suggest that early in the word, more frequent competitors make better candidates for recognition.

2.1.4.5. Summary of findings

1. High frequency items are processed more quickly and more accurately than non-frequent words.
2. Frequent competitors have a higher activation in pre-recognition stages than rare competitors.
3. At late post-access stages of naming, frequency does not exert as strong an effect as it does at early post-access stages.

2.1.5. Accommodation of frequency effects in word recognition models.

2.1.5.1. Logogen model (Morton, 1969)

In the logogen model, "logogens" are posited as being sensitive to both sensory and contextual information. When a logogen receives some predetermined threshold level of input the information to which it corresponds can be utilised in lexical access. The threshold for release of this information is determined by the word's frequency; frequent words have lower thresholds and are thereby recognised sooner.

2.1.5.2. Serial search model, (Forster, 1976)

Serial search models of the type introduced by Forster et al. (Forster, 1976, Paap et al., 1982), predict the frequency effect. Such models posit that each word has a corresponding lexical entry stored in a set of frequency ordered bins. The model predicts that the processor attempts to match incoming sensory information with the stored entries, by searching successively through the bins, starting with the most frequent potential match. The rarer the input target, the longer the search takes and the greater the recognition and naming latency (Garnham, 1985). These models therefore do accommodate the basic frequency effect that frequent words are recognised more quickly than rare ones.

2.1.5.3. Cohort model, (Marslen-Wilson, 1987)

The revised cohort model (1987) predicts the frequency effect. A cohort of word initial hypotheses is generated when the processor receives primary sensory input. Further activation of competitors occurs on the evidence of successive bottom-up information. From this initial set, the hypothesis which matches the input word accrues more activation than its competitors and is recognised. High frequency hypotheses are activated more quickly than rarer ones, and so emerge for recognition more rapidly. The cohort model therefore predicts that at the pre-recognition stage there will be more suitable frequent candidates activated to a higher level than rare ones. The data yielded from gating and priming experiments are compatible with such a model.

2.1.5.4. TRACE: Interactive activation model, (McClelland & Elman, 1986)

TRACE's Interactive-Activation architecture conceptualises word recognition as a multi-level system (feature, phoneme and word levels) in which activation at any level bi-directionally affects activation at adjacent levels. The amount of activational and inhibitory information from units at each level is determined by "the resting activation level of word units or in terms of variation in the strength of phoneme-to-word connections" (McClelland & Elman, 1986) pg. 106. Units representing frequently used connections (frequent words) are conceptualised as having higher resting levels than rare words, or stronger connections in the phoneme-to-word nodes.

2.1.5.5. Connectionist models: e.g. (Seidenberg , 1989a)

In parallel distributed processing architectures (Seidenberg , 1989a, McClelland & Rumelhart, 1985) word representations are activated by a series of connections. The more a system is exposed to a word, the stronger the connections supporting the representation of that word will become. Thus, frequent words, which cause strong connections, will be recognised fastest. "Frequency is simply a measure of amount of learning" (Monsell et al., 1989). Seidenberg and McClelland's model had no specific individual lexical item but performs recognition by computing lexical codes through patterns of activation rather than access to a stored representation. Frequency effects such as those reported by McRae et al. (1990) are captured by such a model. A connectionist model can account for the similarity of rare word versus non-word performances: lexical items are not stored as such, both words and non-words are recognised by the same mechanism of activation of nodes.

2.1.5.6. Cognitive neuropsychological model

Cognitive neuropsychological models (e.g. Morton and Patterson, 1980) are based on logogen type frameworks with "box and arrow" functional architectures. The boxes represent informational stores while arrows indicate the routes along which information travels to connect with or feed into other process functions. Such models are notoriously unspecific about the nature of the processing mechanisms involved in word recognition and say little about the detail of naming and lexical access performances (See Seidenberg, 1989 for discussion). Auditory word recognition is presumed initially to involve a word recognition device (Auditory input lexicon). The state in which the input is received is not specified but it is assumed that both crude and refined information can be accommodated. The frequency effect is mediated through "components which are specialised for the recognition of familiar written or spoken stimuli", and as frequency is a non-semantic property, its effect is felt at the word recognition stage. In many examples of this framework, input and output lexicons are separate entities. Lexical information such as frequency characteristics are typically couched in terms of encodings within a specific box or connection. Some models have suggested that frequency exerts its effect (during naming, for example) in the phonological output lexicon (in a box) or in the process that transports this informations for pronunciation (in a connection) (Coltheart, 987b). Such an account, however does not fit well with McRae et al.'s findings that the frequency effect is not active at the post-access stage of naming. Sartori et al.'s model (Coltheart et al., 987a) has the frequency effect located in the auditory and visual input lexicons. This would explain why frequency effects are felt in some tasks and not in others but the model still fails to specify the mechanism through which the commonness of a word can have an effect on the manner in which the word is processed. One suggestion as to how the frequency effect functions is that when a word is heard or read, a set of semantically related words are activated along with the target word. Rare words are hypothesised to require more additional phonological recoding for recognition than do frequent words (Morton & Patterson, 1980). This still falls short of a principled or explicit description of how the frequency effect is instantiated. That is, cognitive neuropsychological models may be able to locate the frequency effect, but cannot describe its workings.

The frequency effect would appear to be transient or at least less potent over time as more information confirms or inhibits a particular hypothesis (isolation vs recognition). A full account of the effect of a word's frequency on recognition cannot be given, however, without taking into account the frequency of its lexical competitors.

2.2. Activation and competition for word recognition

Current psycholinguistic models of lexical processing (The Cohort Model (Marslen-Wilson, 1987), TRACE (McClelland & Elman, 1986), NAM (Luce, 986a)) assume that input gives rise to multiple lexical hypotheses in the initial stages of word recognition. All such models are bound, therefore, to incorporate mechanisms which allow certain of these hypotheses to become more salient than others and eventually allow one hypothesis to dominate all competitors and attain 'recognition'. The mechanisms by which this process is achieved are typically conceptualised using the metaphors of 'activation' 'competition' and (sometimes) 'lateral inhibition'. This section considers how major modelling genres use activation of, and competition between, simultaneously entertained candidates, to resolve the problem of mapping sensory input onto the intended representations in the mental lexicon. Recent work in the auditory domain (Luce, Manuscript) reports that in the temporal domain, the same metatheoretical comments apply.

2.2.1. Activation

Morton, in discussion of his logogen model (Morton, 1969), was the first to invoke the notion of activation in the sense used here. In Morton's view, the lexicon houses unique feature map representations of words, otherwise known as logogens. As a word is heard, features of the perceived input are mapped onto any matching features in the logogens. When one logogen, activated in this way, reaches a pre-determined threshold level of feature mapping, the logogen 'fires' and recognition is accomplished. The detail of activation proposed was, however, unworkable. Activation of logogens consists of enhancement of a guess concerning the word's identity made early in the recognition process (Quinlan, 1991). Thus, unless the initial guess is correct, then a processor of this sort could not keep pace with the demands of connected speech.

To claim any utility for a mechanism such as activation, one would have to assume that its presence made lexical access and recognition more parsimonious. Inherent in models which include activation is the assumption that activation limits the attempts at mapping input onto mental representations by 'foregrounding' a subset of the lexicon on the basis on some criteria.[3] Although this assumption is acknowledged in the architecture of Cohort-type and interactive-activation models of word recognition, instantiation details differ across models.

2.2.1.1. Cohort assumptions of activation

The first manifestations of the Cohort Model (Marslen-Wilson and Welsh, 1978, Marslen-Wilson, 1987) conceptualised activation as excitation of mental representations solely on the basis of sensory input features: As acoustic information is perceived, the lexical representations which best fit the input are activated. During this early 'access' phase of recognition, *top-down* information is supposed not to affect activation. It is posited that only sensory information is used to stimulate the 'first pass' cohort. Only after the word-initial cohort is established do top-down factors constrain selection and mapping of input onto representations.

In terms of how sensory information is used, the earliest version of cohort (Marslen-Wilson and Welsh, 1978) assumed that input was matched to internal representations on an all-or-nothing basis. All lexical hypotheses whose word-initial elements exactly match the acoustic input are activated. Those that do not match, are not activated at all. Variability of connected speech makes this mechanism unusable. The revised Cohort model (Marslen-Wilson, 1987) acknowledges this and stipulates that hypotheses enter the cohort on a best-fit basis with later stages of word recognition weeding out the less well matching elements. Some features of the original version are retained; the

[3]It is assumed here that making equally serious lexical access attempts on perception of every 'segment' would overwhelm the recognition system and render it inefficient (see Briscoe, 1989 for computational support of this assumption).

revised Cohort model still asserts that the 'best-fit' decisions are effectively based on word-initial matching rather than overall goodness-of-fit. That is, given the input *tape*, the subset of activated hypotheses would tend to share the same word initial sensory information such as *table, tame, take...* rather than being an array with many similar features spread over the word as a whole such as *cape, gape, type...etc.*.

2.2.1.2. Updated Cohort activation features

Even the revised version of the cohort model was prone to two major criticisms pertinent to activation and competition. First, it presumed that the acoustic signal would provide an unequivocal word-initial segment from which to activate the cohort, and second, that contextual information has limited effect on determining the initial cohort characteristics.

Consider first Cohort's heavy reliance on the correct identification of word-initial segments and its failure to acknowledge the inherent phonological variability in the speech signal. Recall that the model posits that activation of the pool from which the target word emerges relies on successful identification of the word initial elements. Critics ask, how parsimonious could such a model be when so much sensory information in connected speech is underspecified and variable? Speech signal variation has various sources; speakers vary in terms of physical vocal apparatus, they have systematic phonological differences, they produce realisational differences, and noise can mask the signal. A word recognition system has to be able to normalise all of these features if it is to detect word onsets successfully. Marslen-Wilson does not ignore the existence of this variability. Instead he claims that variability is not a problem for Cohort - it can handle the variability in the speech signal as most of it is derivable by rule and thereby acceptable. The model supports the idea that the language processor does not treat surface realisation of phonology as deviation but as variation the provenance of which is derivable by rule. Clearly, phonologically regular variation such as that encountered in accent differences is coped with by this caveat. Lahiri and Marslen-Wilson (1991; 1992) find empirical support for the claim that phonologically regular variation does not present the listener with a deviant, and therefore problematic, signal. They show that in gating experiments words with realisational nasalisation such as *ban* (in which the vowel is realised as nasalised due to anticipatory assimilation from the /n/) elicit words with non-nasalised vowels, such as *bad*. This result implies that the word-initial cohort which has been activated by *ban* does not specify the nasality of the vowel - a meaningless feature distinction in English phonology - and thereby contains *bad*.

Second, note Cohort's position on the influence of contextual information; it plays no role in selection of the word-initial cohort. From this, one would predict that for a word heard in context, the array of activated candidates would all resemble the target's word-initial phonetics. If, on the other hand, context has a greater effect in the first pass phase, then one would predict that target identity estimates would be contextually felicitous but would not necessarily resemble the target phonetically. Empirical evidence from gating and priming studies supports Cohort's predictions: Tyler et al. show that, presented with target words in context, listeners' guesses at early gates (before 200 ms of the word) were mostly compatible with the sensory input but often contextually inappropriate (Tyler & Wessels, 1983, Tyler, 1984).

2.2.1.3. Connectionist concepts of activation

Activation of units or nodes within interactive connectionist architectures is propagated by excitatory connections which link nodes between and within levels[4] The amount of input travelling along these connections is modulated by means of weights set at the learning phase[5] but modified in the light of further information over time. The network's interpretation of input is indicated by the activation pattern of its output units. Excitation of initially activated units changes on the evidence of further input. If increased evidence enhances the probability that an initial hypothesis is correct, activation of that unit increases and the internal representation of the word hypothesis accrues further activation.

[4]Although there are also feed-forward connectionist networks with unidirectional links between nodes, I discuss only interactive networks here as this is the genre of model to which TRACE belongs.

[5]Note that TRACE itself is not a learning model.

2.2.1.4. TRACE assumptions of activation

TRACE is an example of a working interactive connectionist model of word recognition (McClelland & Elman, 1986). Sensory input is mapped onto feature level nodes from which activation is spread to all compatible phoneme level units. All mutually incompatible feature units inhibit each other at this point. The activated phoneme units feedback to enhance the activation of compatible feature units, inhibit non-compatible phoneme units, and feed activation forward to compatible word units. A similar pattern of activation and inhibition is mediated from the word level units until one word unit is consistently more highly activated than all competitors. Activation occurs between levels while inhibition only occurs between elements at the same level.

By virtue of the bi-directional connectivity between levels of processing TRACE, unlike Cohort, does not process sensory input in a strictly left-to-right manner. Consequently, the criteria by which activation is governed are crucially different: goodness-of-fit between input and internal representation does not hinge on word-onset information but rather, takes into account overall overlap between input and representational features. TRACE asserts that because of the presence of right context effects, any initial representation must be flexible; rigid specification of word-initial elements as advocated by early versions of Cohort is untenable. Like Cohort, TRACE postulates the arousal of multiple lexical hypotheses. The excitation of feature level units occurs when acoustic input matches the units' feature detectors. Activation of units at any of the three strata (feature, phoneme, and word) affects excitation of elements at the adjacent levels via inter-level bi-directional connections. If units at one level receive activation, all compatible elements at adjacent levels are in turn activated.

2.2.1.5. Comparison of TRACE and Cohort predictions of Activation Patterns

Priming investigations have been used to compare predictions about candidate activation made by TRACE and Cohort architectures. Priming studies show that only word initial matches to the target are primed. Marslen-Wilson and Zwitserlood (Marslen-Wilson and Zwitserlood, 1989) report that rhyme primes are not efficient activators of the words with which they rhyme. Failure to prime appears to persist regardless of phonetic similarity between the rhymes; if word-initial segments are only one feature apart (e.g. *pill & bill*), no priming is afforded (Marslen-Wilson et al., 1988)[6]. Marslen-Wilson et al. claim that this is confirmation that cohorts consist of hypotheses which all match word initially, and which are not just similar as a whole. This would uphold the Cohort view of activation.

2.2.1.6. Metrical criteria for activation of hypotheses

The Metrical segmentation Strategy (MSS) (Cutler & Norris, 1988), although not a full theory of word recognition, does set criteria for the activation of lexical hypotheses. Cutler and Norris' account of activation is based on prosodic feature detection and supports the notion that activation is triggered by detection of strong syllables. Cutler and Norris carried out a study in which listeners hear nonsense words with real words embedded within; for example, *MINTef, MINTayve*. Listeners can identify the real words more quickly when they are embedded within carrier strings with strong-weak prosodic patterns. Cutler and Norris suggest that this reflects differential activation of hypotheses after perception of strong as opposed to weak syllables. They propose that the perception mechanism is attuned to activate arrays of lexical hypotheses when strong syllables are perceived. They do not detail the composition of the 'cohort' activated in this way. Recently, however, an amended version of the Metrical Segmentation Strategy has been incorporated into SHORTLIST, a computationally explicit model of inter-word competition for segmentation (Norris, 993b). The interaction of metrical prosody and activation is discussed is Chapter 5.

2.2.1.7. The Neighbourhood Activation Model

Luce's NAM (Luce, 986a, Luce et al., 1990) conceptualises activation as the effect of stimulus input on stored acoustic-phonetic patterns which correspond to words. Only acoustic information is used in the activation stage; lexical features operate later to bias decision units which are sensitive to higher level influence as well as acoustic-phonetic input. All representations which have some degree of acoustic overlap with the input are activated. Candidates rise in activation until they reach critical word decision levels where recognition occurs. Activation of frequent and rare words occurs at the same rate - decisions are made about frequent words more quickly because hypotheses can surpass criteria for recognition sooner those corresponding to rare words.

---

[6]But see below for discussion of competition between such hypotheses.

Identification within this model is governed by the Neighbourhood Probability Rule. This calculates the probability of the individual internal representations mapping onto input. Unlike dynamic models like TRACE and Cohort, NAM is primarily a visual word recognition model and mapping probabilities are computed once, on the basis of the whole word's features. Neighbourhood size (number of similar competitors) is found to induce activation patterns which aid recognition of rare words (Andrews, 1989): large neighbourhoods facilitate recognition of rare words. Although Andrews' study focuses on written word recognition, the results imply that partial activation of representations of neighbours of a low frequency target may cause reactivation of constituent phonemes of activated word units and boost activation of target nodes. The presence of many neighbours aids recognition of rare words. Frequent words derive no such facilitation because their higher base activation-levels are already too high to benefit from the reactivation posited.

2.2.2. Competition and de-Activation

Simultaneous assessment of multiple hypotheses necessitates that for one candidate to be identified there must be a means by which one word can achieve a special status (whether this be a relative difference between the target and other candidates or an absolute level of activation) - competition mechanisms provide such an environment. Further, when a hypothesis is discredited, there must be a means by which its activation can be reduced. Incorporation of decay and/or inhibition features would accommodate this need (Berg and Schade, 1992). Turning first to competition we see that there are two basic methods of competition incorporated into current models; one activation based, the other involving lateral inhibition.

2.2.2.1. Competition mechanisms in Cohort

Competition in the Cohort model is an indirect mechanism mediated through comparative activation levels. The effect of one candidate's activation does not hinder the activation of other hypotheses. Recognition occurs when one candidate emerges from the pack and becomes sufficiently more activated than any competitor. The different competitor effects felt from strongly and weakly activated candidates are mediated through delay in reaching a criterial difference in activation of candidates: strongly activated hypotheses stay highly activated for longer, even, in some cases, after disconfirmatory information is perceived. The point at which the target and its strongest competitor are sufficiently differently activated is the point of recognition. As there is no finite amount of activation to distribute between simultaneously assessed competitors and as candidates do not directly inhibit each other, the number of hypotheses (i.e. size of cohort) is irrelevant. The factor which delays recognition is the difference in activation level between the target and its highest competitor.

The model also acknowledges the fact that the rapid recognition of frequent words is due not only to the target's intrinsic activation but to the fact that such words are seldom subject to fierce competition. By dint of their status as frequent words and because of the typical partitioning of the cohort[7] high frequency words will rarely have high frequency competitors.

2.2.2.2. Lateral Inhibition and TRACE

The alternative to activation based competition would be a system in which hypotheses directly affected the activation level of their competitors as a means of attenuating the activation of less attractive word candidates. Such a mechanism is incorporated into TRACE and is referred to as 'lateral inhibition'. Inhibition from one hypothesis to another in a spreading activation architecture is conceived of as a gradual process the extent of which is governed by the activation level of the more highly active hypothesis (Berg and Schade, 1992).

Lateral inhibition is characterised as a mechanism by which "the rich get richer and the poor get poorer", (Bard, 1990): highly excited candidates damp down the activation (laterally inhibit) of less potent competitors, thus exaggerating the difference between activation levels. When input causes excitation of a unit, other units on the same level which are incompatible with that input will receive inhibitory feedback. The strength of the inhibition in TRACE is determined by the amount of overlap between the competing hypotheses.

The presence of lateral inhibition in a model would predict quicker recognition of target words than one without (Bard, 1990). Bard asserts that one feature of lateral

[7]Zipf (1935) shows that a word-initial cohort is typically comprised of few high frequency, and many low frequency members.

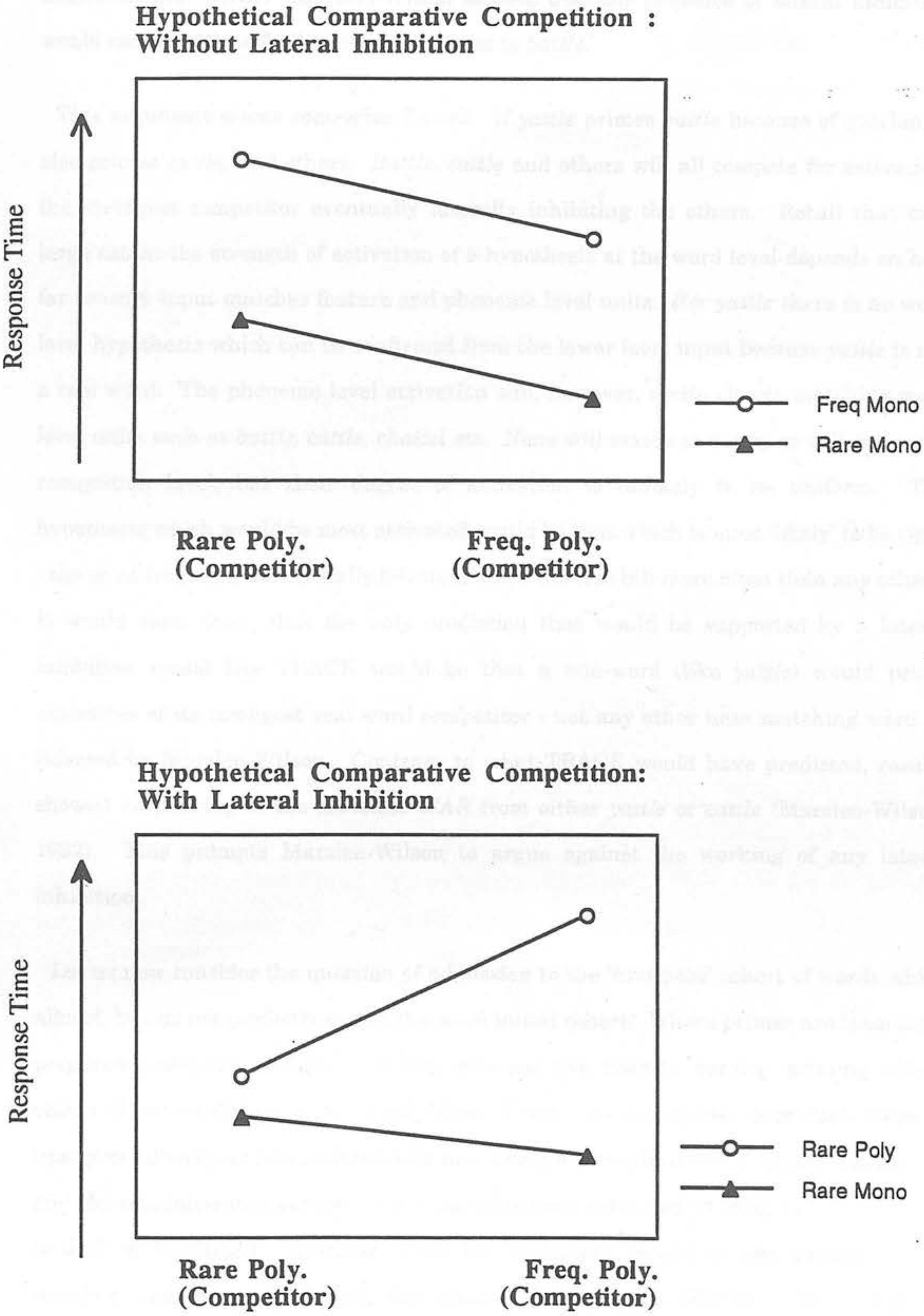
inhibition would be testable: the prediction that a system with lateral inhibition would yield more widely differing competitor effects than one with simple activation based competition. With lateral inhibition, the effect of competitor strength on delay to recognition depends on the strength of the target. There is a greater competitor effect for weaker targets than strong targets. If the model has no lateral inhibition, the competitor strength effect is not present, both weak and strong targets are affected in the same way by their competitors.

2.2.2.3. A Comparison of Competition mechanism predictions

Cohort gives specific predictions for competition patterns for cohorts with a variety of frequency profiles. Consider the case where the input is a frequent word. As input is received, the most common (frequent) hypotheses emerge most rapidly. Thus, frequent words will reach a recognition level (i.e. a critically higher activation than its competitors) more rapidly than rarer words achieve this state of criterial difference. As word recognition is assumed to be a relative mechanism , reaching the criterial level for recognition depends not only on the target frequency but on the frequency of competitors. When the target is frequent but the cohort contains other high frequency candidates, Cohort supports the notion that the target's activation pattern will be the same as that where a high frequency target has only rare competitors. Cohort predicts, however, that the frequent target with frequent competitors will be recognised later. This is because the competitors are highly activated for longer. This delays the point at which the target reaches criterial difference from other competitors. Similarly, rare targets with only rare competitors are predicted to be recognised more rapidly than those with frequent competitors (See Figure 2-1).

Marslen-Wilson (1992) provides a discussion of the predictions which would arise from models which incorporate lateral inhibition. Priming experiments are used to illustrate his argument. A model which incorporates lateral inhibition would predict that where one has, for instance, an original word *battle*, a real word rhyme like *cattle* might initially show priming of an original word's associate, *WAR*. Any priming however, would be short lived as lateral inhibition from the strongest competitor (that which matches the input - *cattle*) would dampen down activation of the original word. If on the other hand the prime is a non-word rhyme (e.g. *yattle*), overlap of its features with those

Figure 2-1: Hypothetical activation and competition patterns in processing models with and without lateral inhibition



of other word representations will cause *battle* to be activated. Marslen-Wilson claims that, as *yattle* does not correspond to a real word, no word level representation would necessarily be excited above the level of *battle*, so *yattle* would not exert lateral inhibition over *battle*. Marslen-Wilson asserts that the presence of lateral inhibition would cause *yattle* to facilitate lexical access to *battle*.

This argument seems somewhat flawed. If *yattle* primes *battle* because of overlap, it also primes *cattle*, and others. *Battle*, *cattle* and others will all compete for activation; the strongest competitor eventually laterally inhibiting the others. Recall that to a large extent the strength of activation of a hypothesis at the word level depends on how far sensory input matches feature and phoneme level units. For *yattle* there is no word level hypothesis which can be confirmed from the lower level input because *yattle* is not a real word. The phoneme level activation will, however, excite closely matching word level units such as *battle, cattle, chattel* etc. None will match perfectly so will not reach recognition level, but their degree of activation is unlikely to be uniform. The hypothesis which would be most activated would be that which is most 'likely' to be right - the most frequent, contextually felicitous word fits this bill more often than any others. It would seem then, that the only prediction that would be supported by a lateral inhibition model like TRACE would be that a non-word (like *yattle*) would prime associates of its strongest real word competitor - not any other near matching word as inferred by Marslen-Wilson. Contrary to what TRACE would have predicted, results showed no priming of the associate *WAR* from either *yattle* or *cattle* (Marslen-Wilson, 1992). This prompts Marslen-Wilson to argue against the working of any lateral inhibition.

Let us now consider the question of admission to the 'first pass' cohort of words which almost, but do not perfectly match the word initial cohort. Where primes are laboratory prepared ambiguous tokens half way between two sounds, varying priming effects obtain (Marslen-Wilson et al., 1988, Moss, 1989). An ambiguous *dask/task* token is nearly as efficient as an unadulterated *task* token at priming *JOB*. Both the ambiguous and the unadulterated versions are apparently both perceived as *task*, so lexical access to *JOB* is facilitated. However, when the ambiguity results in two potential word matches such as *plank/blank*, the token fails to prime *WOOD*. This could be interpreted as vindication of the functioning of lateral inhibition: the extent to which the token matches internal representations causes two likely candidates to emerge, but mutual lateral inhibition stifles either's rise in activation level. An equally plausible account can be made by appealing to competition based mechanisms: priming does not occur because neither token fully matches the input. No hypothesis accrues sufficient activation to break far enough away from the other to reach the criterial difference in excitation levels. The question of the need for lateral inhibition in a competition model is not conclusively resolved.

2.2.2.4. Decay of Hypotheses

As no active inhibitory force operates in Cohort, de-activation of discredited hypotheses is assumed to occur via decay. For a passive decay mechanism such as this to be credible, it would have to dispose of competitors only when the hypothesis was assuredly discredited but quickly enough to remove unnecessary clutter from the working pool of candidates. Cross modal priming has been used to establish the point at which competitors desist from being viable (Zwitserlood, 1989).

Two words from the same word initial cohort were presented; CAPTAIN and CAPTIVE. At a point before the words diverge (i.e. before sensory information distinguishes between the two possibilities - at the offset of /t/) Zwitserlood found that no matter which target was presented, probes related to the most frequent word, (CAPTAIN) such as SHIP, were more quickly recognised. When the probe was presented at the end of the word, only probes which are related to the target are primed (recognised more quickly than they would be ordinarily). From this she extrapolates that early in the word, when the entire 'CAPT...' word-initial cohort is active, the high frequency members of this set are more active than the others. When the full word CAPTIVE is heard, the previously more active candidate CAPTAIN no longer dominates the recognition race; the prior advantage has dissipated. If such a mechanism is operating, one would predict faster recognition times for higher frequency words; this is indeed so. Frequent words reach criterial level for recognition faster than rare words. It must be noted that about 20% of words are not identified until after their acoustic offset (Bard et al., 1988). This suggests that when no winning hypothesis has emerged decay can be delayed and a principal of late closure seems to apply in that hypotheses are be maintained as long as possible even, perhaps, in the light of contrary evidence.

Chapter 3

Methodological Issues

3.1. Introduction

This chapter explores the methodological and data validity issues on which the rationale of the thesis rests. I briefly describe the kind of aphasia in which this study is concerned - fluent aphasia - and the prototypical deficits with which it is associated. I then examine the rationale behind the classification of patients into different aphasic syndromes or symptom complexes and the bearing this has on the subject paradigms employed in aphasia research. Having justified the choice of subjects and their identification, I examine the macrostructural aspects of the empirical paradigms utilised in the thesis. I define the experimental methodologies in terms of their ability to tap into non-conscious and metalinguistic stages of processing and consider how they satisfy the fundamental requirements of the series of investigations which the thesis reports. The details of individual methodologies are left to be described in detail in the body of each relevant experimental chapter.

3.2. Fluent aphasia: a brief description of associated deficits

Aphasia is the acquired linguistic communication disorder present in people whose language centres have been injured as a result of cerebro-vascular accident (stroke) or other cerebral damage. The lesion locus, the severity and physical extent of the injury all have a bearing on the type of deficit which will manifest. In linguistic terms it results in a disturbance in the ability to use a conventional system of signs for linguistic communication. In this thesis I focus on how perceptual impairments manifest themselves as disturbances to the processing required in lexical segmentation and word recognition.

The patients who are the subjects for the experimental work in the thesis have largely been classified as fluent aphasics. The term "fluent aphasia", however, is not unrivaled as a label for this group of patients. Since the advent of aphasiological research there have been disputes about the nomenclature used to label defined syndromes. This has largely been a question of semantics and can be overlooked by anyone wishing to study particular syndromes. Luria's "afferent", "Wernicke's" and "sensory" aphasia 'pigeon-holes' have all been used to describe largely overlapping conditions. But when we ask more probing questions as to the content of such bundles of symptoms the study of the subject become increasingly more complex for neurologists, psychologists, therapists, and linguists alike.

3.2.1. Broad description of fluent aphasia

The deficits of most interest to the current research are those of perceptual processing. Few aphasics present with only one deficit, so I have provided a sketch of a 'prototypical' fluent aphasic's production and perception capacities in order to locate the specific impairments described later in the experimental chapters in a more realistic environment.

Speech production in fluent aphasia is most noticeably very fluent and apparently effortless. Phonemic paraphasias (e.g. off-target planning of phonemes) such as 'orange' being realised as /ʃɔrindʒ/) are often reported in fluent aphasia but the phenomenon is more common still in non-fluent output. At the phonological level, fluent aphasics show considerable deficits, particularly in phoneme discrimination (Blumstein et al., 977a). Auditory analysis of acoustic information is not always reliably performed.[1]. Anomia is often a feature of otherwise normal speech production and anomic speakers are usually aware of their errors. They often appear to make few errors in spontaneous speech as they avoid words they cannot recall by paraphrasing when they are aware of a word finding difficulty. The problem is more obvious if they are asked directly to name an object or picture. For some fluent aphasics anomia is specific to some semantic categories; animate objects, animals, fruit and vegetables. This impairment can occur when few other aphasic symptoms are evident. The speaker can often give the superordinate term of the target word but fail to access any of the category hyponyms.

[1]This aspect of fluent aphasic impairment is explored more comprehensively in Chapter 4.

Non-category specific anomia is often analysed as a problem in accessing the right semantic representation of a target word. Words from any semantic field are likely to be disturbed. Co-hyponyms within the correct semantic field are often given (e.g. If the picture presented is of a CHAIR, a patient with anomia is likely to identify it as TABLE or STOOL). Prompting with the initial phoneme often helps steer the search to the right area of the semantic field. A third anomic type, non-semantic anomia, is the ability to describe objects while not being able to give their names. Frequently used words are more easily retrieved so the spontaneous speech of those with this symptom contains just the most common words in the language.

In extreme cases, where there is a combination of paraphasias and anomia the condition is referred to as 'jargon aphasia' as the output is characterised by strings of unconventional or neologistic utterances. This is typified by the use of a) circumlocutions, b) words inappropriate for context, c) neologisms or jargon (words not in the standard English lexicon) d) non-standard syntax and e) phrases empty of meaning. The overall prosody of speech (intonation, stress etc) is near normal. Like anomia, the majority of word finding problems in this condition are with content words (nouns, verbs, adjectives etc). Jargon aphasia word retrieval errors, however, consist of many production errors involving phonological approximations to real words. (e.g. TRIVET > trowlet; CHASING > cherching). People with jargon aphasia are generally less aware than anomics of their naming errors.

Related neologisms fall into two main categories: those which contain elements of the target word and those which are related to another word in the utterance. Of the first sort, there is sometimes partial retrieval of phonological form of word (e.g. *baloon* > *balon*, *perhaps* > *perhast*). There are also instances of visual confusion (i.e. the words look alike) - *mouse* > *house*); semantic confusion (*chair* > *stool*); or a combination of two types of error such as visual + semantic (e.g. *orchestra* > *sympathy* - via *symphony*); or semantic + phonological (*chicken* > *vowel* - via fowl) In others it appears that little of the intended lexical item is retrieved - *penguin* > *senstenz*, *saucepan* > *ostrum*. Other errors are related to another word in the utterance. These usually involve a perseveration or anticipation of a segment of a word or an entire word or phrase.

Morphological processing can also be impaired in jargon aphasia. Most of the production errors involve distortion of the root of the word. Inflections are kept intact (e.g. CHASING > cherching; DECLARE > dislap (pres.) DECLARED> dislaped (past). It is possible that the speaker incorrectly retrieves the root from the lexicon but then is able to integrate this with morphological/syntactic processes. Another feature of jargon aphasia is the misuse of syntactic categories often referred to as paragrammatism. It typically involves using inflections and function words incorrectly (e.g. THE GIRL IS READING > THE GIRL IS READED, or PUT IT IN THE BOX > PUT IT AT THE BOX.). Using nouns instead of verbs is another common error (e.g. BUT I SEEM TO TABLE YOU SO WELL, SIR.). Note that this kind of error rarely involves the exchange of a function word for a content word or vice versa. Occasionally, processing of syntactic aspects of speech takes the form of omission of grammatical morphemes and words - agrammatism. When agrammatism is associated with fluent aphasia it is usually characterised by a loss of comprehension of grammatical morphemes. The overall comprehension deficit typical of this group is sometimes attributed to impairment of syntactic processing but in most cases syntax is preserved in production.

3.2.1.1. Loss of knowledge or problem of accessing knowledge?

Is the linguistic system intact or has some linguistic knowledge been lost? Are word sets 'erased' from the lexicon? If this were the case, targets from a particular area could never be named, or described, or written or understood. This is rarely the case. Are words 'corrupted' in the lexical store? If they were stored in a corrupted way (if some of the semantic or phonetic information was lost) then we would expect to get the same segments of words partially retrieved each time the word was uttered by a particular patient. For example if /teibəl/ (*table*) was corrupted in storage in such a way that only /_ei_l/ remained, all of that subject's utterances of that word would contain /_ei_l/ and a selection of erroneous phonemes in the gaps. Such a pattern in not usually seen.

Is the form still intact but access to it impaired? If this were so, and the problem lay in the pathway leading to components such as 'semantic boxes', one would expect different mistakes in each utterance, with individual words presenting problems on some occasions and not on others. This is the pattern attested in neologistic jargon aphasia. This suggests that knowledge is not lost but rather that efficient and precise access to it is damaged. It is often claimed that for subjects with this type of processing pattern, performance is impaired but their competence is intact.

3.2.2. Assessment of subjects used in investigations

All subjects were assessed by their therapists using widely used test batteries such as the Western Aphasia Battery (Kertesz, 1979) or the Boston Diagnostic Aphasia Examination (Goodglass and Kaplan, 1972). After this initial screening, subjects were assessed to some degree on cognitive neuropsychologically motivated batteries such as PALPA (Kay et al., 1988). The resultant profiles are provided for subjects in the methodology section of the experimental chapters in which they are taking part.

3.3. Justification for subject paradigms adopted

3.3.1. Single case and Group study methodologies

The following section outlines the debate which is concerned with whether it is ever desirable or possible to categorise aphasics into "deficit subfamilies" for research purposes. I will consider the cases where group research is valid and where single case studies might be a more suitable alternative. In order to consider group study validity we have to ascertain whether there are subjects with deficits which are sufficiently homogeneous to be considered a group. Then we must establish whether there are any means of capturing these deficits in a sufficiently transparent way as to be useful for taxonomy. The question on which the debate hinges is whether or not the variety of acquired language dysfunctions, which result from cerebral damage, consistently co-occur. I discuss the evidence for and against co-incidence of symptoms and the resultant viabilities of clustering symptoms to build up a reliable taxonomy of aphasic syndromes.

3.3.2. Symptom classification

Clearly a belief in the relevance and validity of group based linguistic research with disordered populations is dependent on an equally strong faith in the reliability of classification. Over the last twenty years there has been increasing debate over how to classify aphasic language. Indeed, it is not apparent that anything more taxonomic than individual subject description is valid. Even amongst those who agree that some classification is useful there is no consensus as to whether one should classify patients in terms of individual observable linguistic deficit, regular co-occurrence of certain symptoms, absolute range of deficits or any other number or combination of variables.

The primary concern of classification for psycholinguistics is to capture generalisations for the purpose of drawing conclusions about underlying normal and pathological linguistic functions.

3.3.3. Philosophy of classification

Schwartz pointed out - in her paper disputing the accepted use of classical taxonomic categories, (Schwartz, 1984) - that in trying to bring order to the discipline of aphasiology, the desire for classification blinds the aphasiologist to the fact that "the order and coherence achieved may not truly reflect the order in nature", i.e. that the classification system itself may be erroneous and data extracted using such a system of typology may in fact reflect artifacts of the system rather than the nature of the entities grouped. This begs the question "Why do we categorise?".

3.3.4. Why do we categorise?

The major function of taxonomy is to construct classes whose members share enough characteristics as to make statements posited about them more universally true than statements about any individual of that set. Typologies exist to capture generalisations which in turn can be used to guide the categorisation of new elements and to make predictions as regards further characteristics of a member of a named set. If set A has members with characteristics x,y,z, then if we see an uncategorised element with overt characteristic x then we know to classify it as a member of set A and know that it also has charactereristics y and z. From such typologies we can create groups. What must be considered for work with aphasic populations is whether the members within the group are similar enough for inferences to be generalizable. Are the observations of certain behaviours in one subject going to be useful to make predictions that the same subject will display a further behaviour common in that class? Can we predict that another member of that group will also present with this deficit? Lastly, and perhaps more importantly for aphasia research, can we infer anything about underlying linguistic processes of any member of such groups from looking at the group data as a whole?

3.3.5. Taxonomic methods

Subjects are typically diagnosed on the basis of performance in several language domains (spontaneous speech, comprehension, naming and repetition) (Marshall, 1986) and classified either as presenting with a particular syndrome or cluster of deficits[2]. Such models have evolved partially for the sake of economy: being able to classify a patient in terms of having a specified syndrome allows the use of a codeword to describe his/her condition. The risk in this is that instead of being treated as a shorthand description, too many inferences are drawn about members of the syndrome which are not necessarily correct, and the syndrome label is used as an excuse not to consider the array of symptoms in detail. This clearly has implications for therapy, but here we will only consider how this kind of labelling affects group research.

3.3.6. Group studies

Typologies employed to group patients and symptoms are generally of two types. These have been referred to as psychologically weak, and psychologically strong classifications (Caramazza, 1984). Let us now review the kind of groups which result from each of these typological models and consider how generalizable and representative resultant data would be.

3.3.6.1. Psychologically weak classifications

Psychologically 'weak' or 'polytypic' (Schwartz, 1984) groupings are those in which the range and specificity of deficits with which a patient presents is not absolutely defined but takes the form of a 'family resemblance' (Caramazza, 1984) or array of features. For example, set 1 "Wernicke's aphasia" has characteristics A, (phonemic and semantic paraphasias) B, (phonological perception deficits) C, (poor semantic comprehension), D (anomia), E (fluent yet neologistic production). If subject (1) presents with a minimal selection of the above criteria, s/he will be classified as having Wernicke's aphasia. In other words, a patient need only have a certain, loosely defined number of a specified group of characteristics in order to be classified as belonging to a specified syndrome.

[2]The difference between clusters of symptoms and crudely defined syndromes is crucial. The term 'syndrome' refers to a (named) category defined in terms of a set of deficit characteristics. 'Symptom complex' is used to describe a cluster of deficits with which one patient may present. The term, however, does not imply that the subject has been categorised as having a particular 'condition'.

Caramazza argues that group research, based on such classifications, is invalid in any assertions it makes about co-occurrence of symptoms, co-ordination of functions in language processing in general and inferences about the underlying function or components of processes in particular. Crucially, he argues, the invalidity arises from the inevitable variability of subjects within such groups. The fractionation within syndromes is not restricted to variability of type of deficits - severity of impairment also varies (Marshall, 1986). Thus, two subjects classified as Wernicke's aphasics may have different problems in qualitative terms; one having anomia and little comprehension deficit, while the other has no anomia and a great comprehension deficit, but may also differ quantitatively; one having severe phonemic paraphasias while the other commits only rare paraphasic errors. Clearly, this approach leads to highly variable categories. This makes generalisations about behaviour difficult to defend and consequently makes it more difficult still to defend inferences about underlying impairments.

3.3.6.2. Psychologically strong classifications

Conversely, a psychologically strong syndrome description stipulates strict co-occurrence of a set of symptoms to authorise membership. Strub and Geschwind proposed a 'fixed' syndrome definition[3]. Groups formed on this basis would clearly be more homogeneous than those from psychologically weak groups. Such syndromes would then reflect the breakdown of a particular and discrete process or set of processes (Caramazza, 1986). We must also note the possibility of more than one process being impaired from any one lesion or from more than one injury in one patient. The breakdown of multiple processes would therefore entail the specified malfunctioning of all the manifestations of the impaired processes and any which result from an interaction of these processes in normal language processing. In general, if we classified syndromes in this way the link between the underlying process and its functioning would be more transparent.

Psychologically strong classifications are not, however, beyond criticism. The major objection to this method of categorisation is on the grounds of representativeness. If groups are strictly defined and refer to very specified types of subjects, there is no

[3]Their aim, however, was to group together patients with rarely co-occurring symptoms which is not the objective of psycholinguistic aphasiology.

motivated reason to assume that data will be generalizable to subjects who display only some of the deficits of that syndrome. Thus, data will only be applicable to subjects in this necessarily small category. Furthermore, grouping in this manner is likely to create more syndromes than there are symptoms or indeed underlying impairments. This defeats the economy restriction on classification.

It may seem that both approaches to classification for research are invalid, the 'weak' approach providing non-homogeneous groups of subjects and the 'strong' approach giving subjects not representative of anything but an overly small set of subjects with a highly specified subset of the necessary features, thereby rendering conclusions ungeneralizable. Does this necessarily preclude the use of group studies for research into pathological language functioning? And does it therefore restrict research to the single-case domain? As Newcombe & Marshall (1988) state, the arguments put forward against group study often do not invalidate group research *per se* but rather point out the limitations of the particular classification methodologies used to date.

3.3.6.3. Rigorously controlled groups

A more acceptable method of grouping might be to profile experimental subjects rigorously on the processes most pertinent to the task under investigation. Tyler et al. (1992) adapt such a methodology. They typically assess subjects on a series of on-line and off-line tasks. They argue that this allows insight into processing difficulties as well as impairments of handling final representations of linguistic features. In addition, the breadth of this approach provides details of where processing is normal and where it is impaired which helps to establish the scope of the deficit. Tyler et al. claim that the detail of the resultant data, as well as the linguistic sophistication with which the tasks are designed, facilitates transparency: the profiles are such that one can tell which subjects are impaired in a particular behaviour, and the tasks are sophisticated enough to be able to claim that the behaviour is due to the examined variable and not other deficits. In this way, this methodology provides a basis for both individual inspection of experimental results and a platform from which to decide which data can validly be compared in a group fashion.

3.3.6.4. Limitations of group studies

Just as combination of data from several hypothetically similar sources allows more viable generalisations to be made, much potentially valuable individual performance data is lost (Shallice, 1979). Similarly, minority patterns are ignored and extreme scores are hidden in the averaging out process (Bates & Wulfeck, 1989). What we must consider when working with aphasic populations is whether this averaging out process means that the results are representative of the majority of the subjects (and therefore arguably acceptable for some hypotheses) or representative of an 'idealised' subject who does not exist. It is possible, however, as Tyler et al. show, to conduct a group study while paying attention to individual subject variation. Alternatively, the whole analysis could be done on a single-patient basis.

3.3.7. Single Case approach

Many researchers (Caramazza, 1984, Ellis, 1987, Franklin, 1989) suggest that the only legitimate means of using data from pathological populations to constrain normal linguistic processing models is by using single-case analysis. They claim that categorisation of subjects is an unnecessary layer of analysis which obscures data, and which is therefore theoretically and methodologically indefensible.

Caramazza and McCloskey (1988) challenge the validity of using data gathered from any pathological group to constrain theories about underlying linguistic or cognitive functions. They claim that in relating performance to theory for normal subjects, we assume that the cognitive system of each subject is the same[4]. This assumption of universality means that we can observe performances of normal subjects in experimental conditions and make claims about underlying linguistic processing. The comparable model for brain-damaged subjects must include an extra variable - the lesion. Caramazza insists that the differences between individual lesions, means that performances of subjects (who are impaired due to those lesions) are not equivalent and therefore the performances are not of equivalent type. This renders the averaging of these performances, which are not equivalent, illegal.

[4]Or, within the range of normal variation - which may be more relevant than Caramazza acknowledges. See below for implications of this.

3.3.7.1. Assumptions of single-case philosophy

Current single-patient research methodologies generally rely on one basic premise which Caramazza refers to as the 'fractionation assumption'. This is the belief that selective and discrete components of language functions can be impaired when brain damage occurs. This in turn requires the acceptance of two further conditions. The first is that a *"complex psychological function can be represented in terms of more basic components of processing, or modules"*. The second is that there is a transparent relationship between the dysfunction in pathological language and the underlying process, i.e. that one can infer facts about underlying language process or components from the observation of aphasic language functioning. Chomsky (1988) spelled out the justification for assuming that this is so. He reminds us that when we observe dysfunctions of language in aphasia we are witnessing a breakdown of performance of linguistic functions not the loss of 'ability, disposition, habit or skill'. The fact that some degree of recovery from aphasic symptoms is possible suggests that the system of knowledge, the underlying fundamental cognitive system, is still essentially intact. Therefore, what we see when we observe aphasic performance is a working of this same system but in a slightly different way. We are then at liberty to posit a viable enough connection between the dysfunctioning language and normal language to warrant inferences about the latter being made from observations about the former.

3.3.8. Method of single-case approach

3.3.8.1. Dissociation

If we take these assumptions to be valid, we will come to the conclusion that , in the ideal state, there will be a specific set of 'dissociable' characteristics (each reflecting the breakdown of one particular component) which will be displayed when each function is disturbed by an injury. Patterns of co-occurrence and dissociation of symptoms in one patient give insight into the structure of the underlying cognitive process. The typical illustration of dissociation is as follows: if patient A is impaired in the performance of task 1 but not on task 2, then we can assume a dissociation between the two tasks. For instance, if a subject could not make good lexical decisions on written words but could on auditorially presented words, it would be claimed that the two lexical access functions were separate in some sense. It may be, however, that task 1 is somehow intrinsically easier than task 2. If a second subject B was found to perform task 1 with ease but had trouble with task 2, one could claim a double dissociation between the two tasks. That is, one could dismiss any claim that A's performance was due to intrinsic difficulty of the task (Ellis, 1987). Further, one could claim that the performances on the two tasks reflected the fact that the two tasks required functioning of separate components and that, in each patient, only one (a different one in each) was damaged.

3.3.8.2. Sufficiency condition

When defining the effect of a named impairment on performance the role of concomitant deficits on the performance must be established. Exponents of the case-study approach suggest that this "sufficiency condition" can only be met by an exhaustive investigation of the individual subject's linguistic condition. It may be the case that attribution of a performance to a particular deficit is only possible if all other impairments are noted, but this is not an argument for single case work *per se*, only an argument for rigorous subject profiling. In addition to this rigorous profiling, the detailed study of single patients has facilitated research which previously would not have got underway for lack of a homogeneous group of subjects (McReynolds & Kearns, 1983).

3.3.8.3. Limitations of single-patient research

One of the strongest criticisms of single-case methodology is that it is not a statistically verifiable methodology (Zurif et al., 1991, Bates & Wulfeck, 1989). Caramazza (1991) believes otherwise. He claims that there are "many excellent treatments of the statistical precautions to be followed in single-patient research", but noticeably he fails to cite any. Increasingly, however, small data set statistics and methodologies are being established to enable verification of single-case results; see for example, Multiple Baseline Techniques (Hesketh, 1986), Time Series Analysis (Willmes, 1990), multiple regression correlations (Schriefers et al., 1991) and the Maximum Likelihood Procedure - used to analyse group and individual data, (Bates et al., 1991). This series of analyses has important implications for the increased control of extraneous variables which are more difficult to manage in single case than group studies. Although this arguably allows more robust inferences to be drawn about underlying processes involved in the individuals deficits, it does not necessarily make them more generalizable to the population in general. It also makes single-case data prey to the criticism of losing valuable minority pattern data and extreme scores as statistics typically sum and manipulate results over different tests or trials.

A further challenge is of the validity of using double and single dissociations. Bates claims that the different performances could arise from differences in internal reliability of each variable (Bates & Wulfeck, 1989, Kilborn, 1991). That is, some features are more easily captured by some tests than others. The danger here is that, by only looking at one subject, one cannot differentiate between effects due to normal individual variability and the effect of the variables being examined. Thus, a performance could wrongly be attributed to a pathology when its origin may be in normal variation. This kind of difference is more reliably detected in group studies.

Bates et al. (1989) suggest that traditional single-case studies are not representative for a further reason; that even people with the same underlying deficit (i.e. the one unequivocally identified by the case study) adapt to the deficit in different ways. Because the single case study data is usually not compared with performance of other similar subjects it is difficult to know whether the data is representative of the processing breakdown or reflecting an unpredicted compensatory strategy. The final implication of the idiosyncrasies of individuals is that replication and extension of results are problematic. For the same reason that it is arguably difficult to find converging characteristics between two subjects for the purposes of grouping, it is difficult to find a sufficiently similar subject on which to replicate a study.

3.3.9. Conclusions as to the usefulness of both Single-case and Group research

Both approaches to pathological research have merit, for different kinds of investigation. Individual studies give in depth knowledge of how a particular configuration of deficits constrain normal processing. Group studies allow us to make more generalizable claims about how the loss of a particular function will affect general processing capacities.

The clearest finding from this survey is that if subjects are to be used in group research careful attention must be paid to their profiling. The more sophisticated use of linguistic material and principled design of profiles used by Tyler et al. show that rigorous profiling is possible. This allows the more robustly testable data to be collected in a group fashion without valuable individual performances being masked. As group studies are better at teasing out interaction effects, and providing statistically testable data, the advancement of detailed profiling (such as that used by Tyler et al.) can be seen as a significant enhancement for group analysis.

The present thesis comprises a mixture of case and single group studies. In those investigations which employ group study paradigms, all subjects undergo detailed profiling before they are chosen for use in the experiments. This ensures that the groupings used are well monitored in terms of deficit variation. The two experiments in which a single case methodology is used, provide detailed on-line data, which are statistically testable and allow examination of different aspects of the segmentation process within one patient.

3.3.10. Comparison of aphasic and normal data

This thesis draws on much mainstream psycholinguistic theory both as background to the exploration of segmentation and in the discussion of the aphasic data. In this section I defend the point of view that it is possible to use models built to explain normal behaviour, based largely on data from normal performance, to describe aphasic processing. I argue that is it relevant and appropriate to describe aphasic processing using normal psycholinguistic models, and that aphasic data can successfully be used to constrain such models. In order to do this there must be a recognisible relationship between the aphasic output and the underlying processes. To collect such clean data, we must have a means of eliminating or at least quantifying the degree to which the aphasic performance is contaminated by compensatory strategies which do not reflect stages of normal processing.

In this thesis the cleanness of the data is ensured in several ways. First, the stimuli used in each experiment are psychologically and linguistically sophisticated. The materials are balanced to avoid interference from extraneous variables and rigorous statistical analysis is used to further control any factors which could not be balanced *a priori*. Second, the paradigms used are established as reliable and sensitive measures of psycholinguistic processing. They have all been used to amass a wealth of normal data on aspects of processing related to word recognition. Further, the paradigms used can all be described in terms of the degree to which they reflect both non-conscious (automatic) and metalinguistic stages of processing. Third, the theoretical models employed as frameworks for conceptualisation of the resultant data (Cohort Model, (Marslen-Wilson, 1987); TRACE, (McClelland & Elman, 1986)) are detailed and explicit in their description of the component levels of processing in word recognition. In addition the experimental results for the aphasic group are matched against those of (in the majority of cases) carefully matched controls on an individual subject by subject basis. This helps ensure that the relationship between the impaired performance and normal performance is as transparent as possible (See above for expansion of the idea that aphasics are underlyingly normal processors).

3.3.11. On- and Off-line experimental paradigms

Both on- and off-line methodologies are employed in the course of this thesis. Off-line studies yield data which (most obviously) reflects the listener's performance with regards to the properties of the percept's final representation. There is an element of the response which does not necessarily have to be linguistically driven. I refer to these elements as metalinguistic components. In order to make linguistic and psycholinguistic claims from the resultant data, the size of the metalinguistic element of each experimental design should be quantified. A clear assessment of the size of the metalinguistic component in the designs used facilitates more accurate claims about how the data can be used to describe aphasic impairments and constrain normal processing models.

In Experiment 1 (Chapter 4), a discrimination paradigm is used. The choice between the alternative matches is, to some degree, explicit in so far as listeners are aware that they must match the stimuli to one of two choices. The listeners are not made explicitly aware of the independent variables along which the stimuli differ and the materials are opaque in this respect[5]. After perception of the stimuli, the listener has the opportunity to invoke metalinguistic knowledge to aid their response. I would argue that the responses made at this stage reflect linguistically primed metalinguistic intervention.

---

[5]That is, the pattern of frequency, length, plausibility and acoustic variation is not discernible by the naive subjects.

The second Experiment (Chapter 5) is a word spotting task. The first stage of which involves the employment of automatic processing components to detect words within environments which vary along a prosodic dimension. The ease with which the target is detected is dictated by non-conscious processing. The task is considered off-line in this instance, however, because the response method (dictated by the abilities of the subjects) is a picture pointing paradigm. This response stage entails a metalinguistic element - the aphasic subject could be appealing to other levels of cognition to match the detected word to a picture. As each target material is presented in both variants of the crucial independent variable (strong versus weak metrical context) any specific metalinguistic strategies influencing the response would be the same for both contexts. Random use of metalinguistic features would be a matter for discussion in the results section but not an *a priori* reason to suggest that the task was invalid as the task does not require the listener to reflect consciously on the representation that has emerged automatically (Tyler, 1992).

The third experiment (Chapter 6) entails similar opportunity for the automatically accessed final representations to be supplemented by metalinguistic reflection. The task involves the listener accessing representations of words which share some degree of phonological overlap with the explicitly presented tokens. Again the response method is a picture pointing paradigm and offers the chance of intervention by metalinguistic features. The likely metalinguistic elements are examined in the analysis of the data.

The final two experiments reported in the thesis employ the same on-line methodology - gating[6]. Because on-line studies tap directly into automatic processing by strictly dictating the amount of a stimulus presented to a subject at the time a response must be given, they clearly provide the cleanest data. They also allow the examination of the listeners' (automatic) manipulation of input at the interim stages of processing and their interpretation is not dependent on making assumptions based on the state of the final representation of the listeners' response.

But can off-line tasks teach us anything about the real-time processing problems of the

[6]Discussion of the validity of claiming that gating is an on-line methodology and other methodological aspects of the paradigm are explored in detail in Chapter 7.

aphasics taking part in the studies? Off-line information can be used as an indirect indicator of on-line processing in that the data provided reflect the end point of the process examined. This relies on the assumption that if the end product of the process is not available (e.g. if a word is not spotted, or discrimination between two percepts is not correctly made), then one or more of the processes required in this task has broken down. Off-line tasks allow insight into the end point of processing - the effect of the independent variables on the final lexical representation. In order to extrapolate to on-line processing capacities we must make the assumption that if the end product of the process is not available (e.g. if a word is not spotted, or discrimination between two percepts is not correctly made), then one or more of the processes required within this task has broken down. This is an analogous assumption to that made in all psycholinguistic experimentation which uses off-line methodology - that variables which delay the emergence of the end-products of processing (e.g. word recognition) affect some intermediate[7] stage of processing which in turn causes delay in the emergence of the process's final outcome.

The experimental paradigms employed in the thesis draw much from mainstream psycholinguistic research methodologies. The assumptions on which the models rest have been rigorously researched and are theoretically motivated. The adaptation of the paradigms for use with aphasic subject samples often introduces the possibility of involvement of metalinguistic elements. However, I would argue that with an adequate model of processing (which the Cohort Model and TRACE provide) and an assessment of the potential for metalinguistic components, valid conclusions can be drawn from these methodologies. Further, the comparison of performances between the aphasic and normal control groups gives a comparative estimate of the size of the normal metalinguistic intervention in any given task and allows extrapolation as to the underlying changes in processing.

---

[7]In this instance the word 'intermediate' is used loosely to mean a stage at any point in the processes, not necessarily one at the the final stage.

Chapter 4
Interaction of acoustic and lexical information in segmentation.

4.1. Introduction

In this chapter I examine how fluent aphasics with impaired auditory perception use two types of cues to segmentation. The first of these is the acoustic variation at word boundaries, the second is the lexical level biases which emerge from competing segmentations of the speech stream. I explore aphasic preferences for segmenting the speech signal and consider whether there are any acoustic cues sufficiently reliable or potent enough to be used by perceptually impaired listeners. In addition I examine aphasics' interpretation of speech signals in which acoustic cues are not sufficient to indicate the speaker's intended segmentation and try to identify any tendencies to segment in accordance with particular strategies.

One way to examine how auditory perception deficits might affect segmentation is to consider the processing of a speech string which has two valid minimally different (in acoustic terms) parses and in which the different parsings depend on where the listener segments the signal. Consider the string /ɪtspreɪz/; it has two possible interpretations - *its praise* or *it sprays* - the difference between the two lies at the lexical level and involves the location of the word boundary. In this investigation I explore the differences between the way aphasic and normal listeners segment such strings and employ the results to make claims about aphasics' relative use of acoustic material and lexically based biases in segmentation.

4.2. Acoustic cues to segmentation

Models of language processing adopt either an *active* or a *passive* view of how the listener segments the speech stream into words. Proponents of *active* models suggest that lexical access attempts are made once the word beginnings are detected and that the processor uses specific cue searching mechanisms to find these word junctures (Lehiste, 1960, Nakatani & Dukes, 1977, Cutler, 1986, Cutler & Butterfield, 989a). Active models support the notion that prosodic and acoustic features of the speech stream as well as phonetic and allophonic variation of consonants are used as aids to segmentation. In this chapter I will focus on the potential cues to segmentation that emerge from acoustic variation at word boundaries.

Traditionally it has been claimed that segments which occur at word boundaries are phonologically different from those same phonemic elements when they occur within words (Hockett, 1958). This claim has often been accompanied by the assertion that this leads to perceptible differences between phonemically identical phrases with varying juncture like *Nye trait*, *night rate* and *nitrate* (Hockett, 1958). Empirical research has shown, however, that juncture phenomena are not only acoustically unreliable, but are often perceptually uninformative with regard to juncture identification. Lehiste (1960) isolated allophonic variation, intensity and duration as being features most indicative of juncture. She highlighted the following features as being particularly strongly correlated with juncture: greater length of the post-junctural allophone, aspiration of word initial voiceless stops, greater length of initial voiced stop allophones compared to voiceless counterparts, greater length of initial nasals relative to medial or final allophones, differences in formant steady states in the allophones of /l/ (depending on position relative to juncture) and laryngealisation of post-junctural vowels which are followed by a glottal stop. Furthermore she posited that these features were detectable by listeners and used as perceptual cues to word boundaries. Perceptual studies, however, (Nakatani & Dukes, 1977) indicate that only some of these features, which are commensurate with noticeable variation in the acoustic signal, are perceptible as reliable indicators of word boundary. Nakatani and Dukes concluded that post-junctural cues were the most salient and only /l/ and /r/ had word final allophones which gave useful boundary cues. In addition, Nakatani and Dukes found, as Lehiste had predicted, that glottal stop and laryngealisation at the onset of post-junctural vowels were found to be reliable cues. Word duration, on the other hand did not prove useful, even though it varied considerably and systematically with juncture position. They concluded that only qualitative features of the signal are useful boundary indicators.

To date there has been little in the aphasic literature to indicate how listeners with impaired auditory perception utilise what acoustic information there is to aid lexical segmentation. The literature does, however, provide material on the wider domain of general acoustic perception by aphasics. It would be illuminating to establish the extent to which acoustic variation in the speech signal is available to fluent aphasics to assist segmentation.

4.3. Acoustic perception by fluent aphasics

Auditory perception and processing by aphasics has been analysed in numerous phonemic and acoustic level detection tasks. The tests have been diverse in methodology; some have followed a discrimination paradigm (Blumstein et al., 977a, Basso et al., 1977, Consoli, 1973, Carpenter & Rutherford, 1973, Jauhiainen & Nuutila, 1977, Varney, 1984) and others have tested identification (Blumstein et al., 977a, Blumstein, 977b). The tests have been varied with respect to linguistic/acoustic feature; Varney (1984) and Juahiainen & Nuutila (1977) tested perception by manipulating the input at the phonemic level while others manipulated Voice Onset Time (henceforth VOT) (Blumstein, 977b, Blumstein, 1981, Basso et al., 1977), formant transition length (Blumstein, 1981) and other spectral and temporal acoustic level elements (Carpenter & Rutherford, 1973). In addition, quantitative and qualitative aspects of acoustic/phonemic detection abilities have been correlated with different deficits or symptom complexes in a variety of ways. Here I will review the phenomena related to how fluent aphasics process acoustic information.

The most detailed studies concerned with aphasic auditory perception have considered discrimination[1] between and identification[2] of phonemes which differ along some

[1]Discrimination is defined in terms of a subject's ability to listen to two tokens and make a same-different judgement on them. Discrimination relies on the listeners' ability to detect differences between two or more presented stimuli in terms of the variable under investigation.

[2]Identification, on the other hand, firstly relies on the speaker detecting input (in terms of a particular variable) in a way which will distinguish the input string from all potential alternative interpretations of the string. Further, it requires the ability to categorise input on the basis of information received. Identification often involves analysing input which varies along a continuum and assigning it one of a limited selection of labels. This is achieved by appealing to the mechanism of categorical perception.

acoustic dimension. The aim of the measurement and description of those features which are problematic for aphasics is to identify the acoustic correlates of auditory perception deficits.

Acoustic perception breakdown has typically been quantified in terms of the distinctive feature contrasts of voice, place and manner. Blumstein et al. (1977a, 1977b, 1981) and Basso (1977) make comparative analyses of how fluent and non-fluent aphasics with both good and bad general comprehension attend to voicing information and use it to identify and discriminate auditory input. Both discrimination (Basso et al., 1977, Consoli, 1973, Blumstein et al., 977a, Carpenter & Rutherford, 1973) and identification paradigms (Blumstein et al., 977a, Blumstein, 977b) are explored in the literature surveyed.

Among the acoustic correlates of the voice element of a phoneme certain features are generally agreed to be germane: VOT is thought to be critical (Lisker, 1967) the slope, degree of cutback and onset of frequency of the first formant have also been identified as indicative of a phoneme's voice characteristic (Cooper et al., 1970): duration of intervocalic closure (Lisker, 1978) and intensity of burst (Zue, 1976) are reported to be greater in voiceless than in voiced stops. Research with various aphasic sub-populations has examined aphasic performance in acoustic discrimination and labelling targets which are manipulated in terms of VOT (Blumstein et al., 977a, Blumstein, 977b, Blumstein, 1981, Basso et al., 1977).

VOT can be defined as the timing relation between the release of the burst in a stop and the onset of glottal pulsing. If the two processes occur simultaneously then the sound produced is perceived as voiced, if glottal pulsing is delayed for something in the order of 30-35ms then it is perceived as unvoiced. The VOT is generally held to represent not just the timing relation of the glottal movement and burst release but also to be representative of concurrent acoustic aspects of the voiced consonant such as increase of intensity and duration of release, starting frequency of the first formant and presence or absence of friction on consonantal release (Blumstein et al. 1977, Lisker, 1964, Stevens, 1974).

Normal VOT discrimination and identification ranges have been established using synthesised acoustic continua which vary along the VOT dimension. Studies report that for English any point on the continuum will be labelled as one of two discrete categories, either voiced or voiceless, and that discrimination between two points is only reliably achieved if the stimuli fall one into each of these two categories. When the VOT is less than zero (i.e. the glottis movement was initiated before consonantal release) the sound will be systematically identified (labelled) as voiced. If VOT is greater than 50ms (that is, when there is a delay of more than 50ms between release of consonantal burst and movement of the glottis) then the consonant will be systematically perceived as voiceless. The recognised crossover point where labelling would change from voiceless to voiced is between 0 and +50ms. This stretch of VOT continuum can be referred to as the boundary zone (Basso et al., 1977) within which labelling will be inconsistent across subjects.

Discrimination ability is established empirically by presenting pairs of stimuli which occur at a series of points on the VOT continuum and which are set 20ms apart. The literature reports that discrimination is more reliable between stimuli with certain VOT values than it is with others. Studies show that pairs with VOT values of 20-40ms, 30-50ms, and 40-60ms are reliably discriminated between while those outwith this range are not.

4.3.1. Processing of voice contrasts

Investigation of aphasic perception and use of VOT variation has shown a depreciation in the overall efficiency in comparison to normal optimal detection of VOT differences. In a discrimination experiment Blumstein et al. (1977) found that one group of patients (classified as 2 Broca's, 1 Mixed Anterior, 1 Wernicke's, 1 Conduction, and 2 Anomics) performed comparably with normals in terms of range along the continuum where responses were most accurate. That is, the aphasics were most accurate where VOTs differed at 20ms intervals situated at 20-40ms, 30-50ms or 40-60ms. However, even at these loci efficiency could be as low as 80% whereas normal rates would be rarely less than 95%. A second group was less than 60% efficient at discriminating between VOT's differing by 20ms no matter where on the continuum they were situated. The highest success rate (60% success) was achieved with VOTs at 30-50ms, 40-60ms, 50-70 ms. This represents a slightly skewed boundary zone; one within which the categorical perception mechanism does not function stably and one skewed in the direction predicted by an inability to accomplish fine-grain temporal resolution.

Identification ability is also found to be reduced. Aphasics of whatever deficit type were reported to be of below normal efficiency in their percentage correct responses. There also tends to be a wide cross over point within which identification is inconsistent. Blumstein et al. reported that Wernicke's aphasics presented the most consistent pattern of results; they had a persistent deficit in labelling of sounds on a VOT continuum but found discrimination relatively unproblematic. It was concluded that the Wernicke's aphasics found it particularly difficult to maintain stable category labels and it is this which makes their labelling so erratic. It is possible that every mistake of this sort made by the listener enormously complicates the parsing of the phonology into meaningful sentences. The extra workload entailed would be very problematic in terms of integration in real time. There was no correlation, however, between performance on the labelling and discrimination tasks on one hand, and general comprehension on the other. With so many uncontrolled intervening variables, this is not surprising.

Others have viewed identification deficit as qualitatively uniform across groups and accounted for variation in quantitative terms. The results of Basso's investigation (1977) suggest that in its mildest form the impairment still leaves a recognizable boundary zone intact albeit outwith the normal range. Impaired listeners of moderate ability will show only a trend towards identifying a stimulus as voiced in the voiced region and voiceless in the voiceless region. Efficiency is always depleted in comparison with that of normal listeners. The most severe form is that in which no trends emerge and where Basso proposes that labelling is random.

4.3.2. Processing of place contrasts

There are numerous identified acoustic correlates of place features. For stop consonants the following are relevant: intensity differences at certain frequencies (700Hz - 10kHz) (Halle, 1957); duration of VOT - velars show the longest and bilabials the shortest VOTs (Peterson & Lehiste, 1960); duration of closure - bilabials have the greatest mean duration and velars the shortest (Zue, 1976, Edwards, 1981). Bilabials are indicated by lack of main resonance in 0-10kHz range and weak burst intensity.

Alveolars are indicated by abrupt rise of spectral level above 4kHz while velars exhibit a concentration of energy in the middle of the spectrum. Carpenter and Rutherford (1973) carried out a discrimination investigation of aphasics' ability to discriminate between place features in which they manipulated the formant shifts of consonants in specified ways. The exact nature of aphasic impairment is not recorded but subjects are referred to as receptive aphasics. The study reveals that when an entire formant shifts e.g. /fig/ - /fib/ then this change is 100% recognizable. When the shift is only partial the success rate of discrimination drops to 40% (Carpenter & Rutherford, 1973). Tallal (1975) tested the effectiveness of the length of the third formant and reports that although there was a trend toward improved discrimination with increased formant length, this improvement was not significant. Blumstein et al. (1977) report that fluent aphasics have significantly greater problems in discriminating place than voice contrasts. The conclusion to the Blumstein study is that the difficulty arises because of a difficulty in extracting information on "direction, rate and extent of rapidly changing formant transitions" (pg 27). Elsewhere it has been suggested that aphasic discrimination of phonemes differing in place of articulation is 15% below normal success rates (Jauhiainen & Nuutila, 1977).

4.3.3. Processing of manner contrasts

Studies of aphasics' ability to detect the acoustic correlates of manner of articulation features have been scarce. Acoustic research has identified a number of features concomitant with each particular manner of articulation. There are thought to be five acoustic correlates to the 'stop' feature: occlusion, which entails temporary absence of acoustic energy; transience, which is the release of closure and is manifest acoustically through a peak of duration at about 10ms (Cooper et al., 1970); frication and aspiration, which result from turbulence in the glottis; and transition (the interval of time from the point at which formants are first detectable in the aspiration stage to the point of formation of the acoustic vowel target). Fricatives typically produce a turbulent airstream whose acoustic consequence is increased levels of noise. Within this class, sibilants have the greatest intensity (Ladefoged, 1975). The spectra of non-sibilants tend to concentrate together in formant-like bands. Affricates differ from fricatives in that they consist of a closure and produce less fricative noise than the fricative sounds.

Furthermore, the duration of onset of frication to the time of peak amplitude of fricative noise is shorter for affricates than it is for fricatives.

The only study of aphasic acoustic perception of manner features was that comprising part of the Carpenter and Rutherford (1973) study which focussed on temporal aspects of phoneme discrimination. They considered how well aphasics could detect the difference between consonants when a stable acoustic intensity was maintained across compared consonants but in which durational differences led to variation at the phonemic level. Duration of fricative noise was the crucial feature which distinguished phonemes in terms of manner. The study found that aphasics had a success rate of only 20%, suggesting that quantitative differences such as duration are amongst the most difficult for this group to process.

In sum, the acoustic contrasts which prove most problematic for the aphasic listeners appear to be chiefly quantitative. Recall, however, that Nakatani and Dukes suggest that the identification of word juncture relies on the ability to discriminate features which vary qualitatively. This might lead to the simple prediction that the acoustic perception impairments with which aphasic listeners typically present, would not, in general, lead to difficulty in processing those contrasts salient for word boundary detection. It is clear, however, from a more detailed examination of the acoustic perception data, that such a prediction does not take into account the knock on effect of these specific failures: the failure to correctly process quantitative features results in a general degradation in processing. Predictions are made more difficult still because the discrimination abilities required to make word boundary choices between the stimuli in the experiment described below are not at the level of phoneme discrimination.

4.4. Implicit segmentation

Not all models of processing have taken the view that acoustic cues to word boundary are of paramount importance. While active models support the idea that the language processor employs an active strategy of searching the incoming acoustic stream for specific targets which indicate word juncture, other models posit that segmentation is resolved in tandem with word recognition; that it is not an autonomous process but is a by-product of successful lexical access rather than a pre-requisite of it (McClelland & Elman, 1986a).

In some processing models, recognition is considered a highly interactive operation in which many of the functions of recognition are distributed throughout the system. In interactive activation models such as TRACE (McClelland & Elman, 1986b) for example, input may be underspecified or highly contaminated by noise. McClelland and Elman cite this as a fundamental reason why heavy dependence on features at the acoustic or phonemic level would not be reliable. In general, proponents of such models stress that cues are of *limited* use in segmentation and support their argument by pointing to findings that contextual effects can override even adequately specified acoustic data (Cole & Jakimik, 1980).

Being interactive in design TRACE performs lexical access and segmentation not as autonomous functions but rather as products of the same set of simultaneous processes. TRACE is designed largely to ignore fine grained phonetic detail and analyse sensory input at a phonemic level[3]. Information builds up confirming the validity of lexical hypotheses. When a small advantage emerges for one candidate and continues to be confirmed a mechanism of winner-take-all competition magnifies this originally small advantage and the strongest lexical candidate overrides all competing hypotheses. Recognition of a word is thus tantamount to the processor deciding that a word has just been completed - that the word's end has just been detected. The interactive model described uses a system of 'between all adjacent levels' activation and 'within all levels' inhibition. The advantages which any one lexical hypothesis may have over its competitors can, in principle, be a function of features at all other linguistic levels; syntactic, semantic etc.[4]. One can infer, then, that information from any level can help confirm or inhibit 'segmentation' occurring at any point in the acoustic signal. Segmentation should therefore pose fewer problems if the input is such that it uniquely specifies one lexical item as this can quickly be confirmed by feedback from the lexical level. Much of the lexicon, however, is not like this: perhaps as much as 60% of phonemically specified words, even if they are acoustically clear, are not unique at their offsets (Luce, 986a). The implications that this has for the segmentation problem are clear: the listener is consistently presented with words embedded within other lexical

[3]Although it does begin at the feature level.

[4]Although TRACE does not feature a semantic level.

hypotheses (e.g. *cat* in *catalogue*) and with overlapping hypotheses with alternative lexically appropriate boundary locations (e.g. *an ocean* and *a notion*).

Simulations using TRACE indicate how the processor would deal with input which is ambiguous as to segmentation point. The premise is that the interpretation which receives the most confirmatory and least inhibitory feedback will be selected and that the degree and nature of this feedback is a function of features of the language. The most prominent features of the language will exert the most influence. Thus in ambiguous contexts where one potential segmentation would result in interpretation as a frequent word and one a less frequent word, the interpretation as a frequent word would be favoured as it would receive more positive feedback. Computational simulations indicate that the architecture of an interactive activation model can get a long way in segmentation using such biases.

McClelland and Elman (1986) make specific reference to a length bias. They propose that if a string has two possible segmentations which leave lexically valid phrases, one which has early segmentation and one which has late, then, all other things being equal, (e.g. word frequency) later juncture will be favoured. That is, if presented with a string such as /ɑrtrʌst/ then segmentation as [ɑrt rʌst] would be preferred over the alternative [ɑr trʌst]. The word activated first accrues most information to confirm it as the dominant hypothesis making it harder for later emerging words to inhibit the longer established candidate. Frauenfelder and Peeters (1990) carried out further simulations using the same computational model. Their results confirmed that initially activated words accrue positive activation to such an extent, and exert such influential lateral inhibition on their lexical competitors, that they dominate other emergent lexical hypotheses completely. However, as stated earlier, frequency is confounded with word length. I posit therefore that this relation will override the more mechanically based bias of blind accrual of activation and cause the listener to segment in favour of shorter words. The more important aspect of the simulations of TRACE was their indication that even without acoustic or detailed phonemic information, definite preferences would be exhibited for one particular type of segmentation.

This suggests that even in degraded listening conditions or when perception is impaired, and detailed acoustic information is limited, segmentation is possible due to the processor's ability to utilize statistical probabilities to make implicit choices. Although TRACE cannot confirm which linguistic features are utilized by the processor's architecture, behavioural data suggests lexical features such as frequency, plausibility and imageability are influential even when damage occurs to the system (Tyler, 1985). Gating experiments indicate that the frequency effect is robust in word recognition even when all the available sensory input has not yet been perceived.

4.5. Lexical Biases

One aim of the current chapter is to evaluate the role of biases, for aphasics and normals, in parsing a speech signal which has two potential parses. The materials used give rise to three sources of lexical bias as potential predictors of segmentation decision, namely, frequency, plausibility and length.

4.5.1. The frequency bias

First let us explore the frequency bias. Listener biases are assumed to be extant because of the properties of the language itself. The exposure a listener has to language is not uniform. Some words are heard more than others; the advantage this affords them is referred to as the frequency effect[5]. It has long been established that the word frequency effect heavily influences the latency and accuracy of lexical processing: words which occur frequently in the language are responded to more rapidly and effectively than rare words (Forster & Chambers, 1973, Frederiksen & Kroll, 1976, Monsell, 1985). This predicts that subjects will parse the ambiguous strings to give a frequent first word. (Below I examine why the frequency bias operates in favour of the first item rather than the second in the phrase). That is, given the string /grasprais/, the subject will segment it as *grass price* rather than *grasp rice* as *grass* is more frequent than *grasp*. The aphasic literature also attests to the influence of word frequency: aphasics are sensitive to frequency, with increased frequency of occurrence increasing the likelihood that the aphasic will recognize the word (Schuell et al., 1961).

---

[5]A more detailed account of frequency effects is presented in Chapter 2.

4.5.2. The plausibility bias

Some phrases are more plausible than others. This plausibility bias has been reported as influential in aphasic word recognition (Schulte, 1989). Schulte cites meaningfulness, usability and personal familiarity of a word as being relevant to recognition performance of aphasic listeners. In the context of this investigation, the plausibility bias refers to the likeliness that the string has one interpretation rather than another. I predict that on hearing the string /birdrɪps/ the plausibility bias would lead to the parse *beer drips* rather than *beard rips*, as the first interpretation is more likely than the second. In effect, plausibility refers to the likelihood that these words would occur in tandem. Thus, plausibility shares with frequency, the element of having higher incidence in the subjects' repertoire and linguistic environment than its competitor. However one should note that a phrase like *tall tree* is more plausible than *blue tree* not necessarily because the former is found more frequently in the language but because the listener's world knowledge tells them that trees are rarely blue. It is predicted that the plausibility effect, due to its interpretation of world knowledge, is a higher level effect and as such, would be operational at a later stage of processing. Further, confirmation of use of such an intuitively appealing bias would reflect a certain degree of parsimony in the language processor.

4.5.3. The length bias

The third bias to be examined in this investigation is that of length of pre-junctural word. TRACE (McClelland & Elman, 1986a) predicts that in the absence of conflicting information, all else being equal, a length bias exerts its influence in favour of a "long-word first" parse. That is, the language processor has a preference for late versus early closure in segmentation. If the string is /ɪtswɪŋz/ TRACE predicts that the preferred parsing would be *its wings* as opposed to *it swings* on the grounds that *its wings* has a later segmentation point (Frauenfelder, 1990). Details of the mechanism and reasoning by which this result is achieved are given below. The basis for this bias, however is less solid. An equally plausible prediction emerges from examination of lexical statistics. Zipf pointed out (1935) that there is a correlation between commonness of occurrence and length of word; short words are more common and common words are shorter than rarer words. The prediction of early, overgeneration of segmentation decisions is also intuitively appealing as these would require less processing to recover from than undergeneration. In cases of ambiguity then, I predict that segmenting to give early juncture (which statistically would more often lead to correct interpretation) would be the more parsimonious strategy to adopt.

4.5.4. Predictions

I propose that in attempts to segment the speech stream those with degraded processing of acoustic detail (aphasics) will still have recourse to such biases. I posit that as biases are essentially representations of statistical properties of the language, and thereby manifest their influence over a wide distribution in the cognitive process, it is unlikely that their influence is fully eliminated by cerebral damage. I hypothesise that the biases will be resistant to damage and will continue to influence segmentation and lexical access tasks.

4.6. Method

4.6.1. Auditory discrimination Paradigm

An auditory discrimination paradigm with visual matching responses was adopted to test fluent aphasics' ability to use acoustic differences and lexical biases to allocate word junctures. The null hypothesis is that the aphasics' low-level perception deficits will not cause their assignment of word boundaries to deviate significantly from the boundary assignments made by unimpaired listeners. The prediction here is that, given their impaired manipulation of low level auditory information, aphasics' use of acoustic juncture cues will be below normal levels and that they will be more prone to bias-predicted interpretations of the materials than normal listeners.

4.6.2. Hypothesis requirements

The hypothesis requires a way of attributing juncture allocation to the use of acoustic information rather than to phonological level differences. Presenting pairs of strings such as *a notion* vs *an ocean*, which are almost identical at the phonological level, but differ in terms of acoustic features at the word boundaries provides an efficient way of investigating this phenomenon.

4.6.3. Further constraints

The response options were limited by the nature of the stimuli. Verbal response as an indicator of interpretation of the stimuli was not suitable for two reasons. First, the acoustic differences between the alternative responses were minimal; it would not be judicious to rely on the investigator's re-interpretation of the subjects' verbal responses. Second, many subjects had phonological production deficits which rendered the interpretation of their spoken responses more unreliable still. Picture matching was also ruled out as the set of materials which differ minimally only by juncture position is small and contains few pairs which are both imageable enough to be pictorially represented. A visual matching response method was therefore considered most suitable and a visual lexical matching paradigm was adopted.

4.6.4. Design and Materials

A mixed design was used. The dependent variable is the correct segmentation (from a pair of alternative choices) of the ambiguous string. The independent variables are frequency of first word (frequent or rare), plausibility of phrase (more plausible or less plausible) and lateness of juncture (early or late)[6]. Twenty-six pairs of two- or three-word tokens which contained a combination of the independent variables were constructed. Both members of each pair is identical at the phonetic level (/ɪtspreɪz/), but the assignment of word boundary at different points in the signal results in two independent parses (*it sprays* or *its praise*)[7] . The materials formed two experimental conditions. The first was such that acoustic cues and lexical biases conspired to give one interpretation of the string (listener hears *see lying*, i.e. acoustic cues are commensurate with *see lying* interpretation, and the lexical biases - in this case the frequency bias - favoured the same interpretation, i.e. *see* is more frequent than the

---

[6]Frequency of the initial word in each token was measured using the standardised frequency counts provided by Francis and Kucera (1982). The word with the highest frequency count was assigned the "frequent" label, the other was referred to as "rare". For instance *grass* has a frequency of 61 and would be labelled "frequent", so its mate with a frequency of 23 would be labelled "rare". The experiment also required a measurement of the second variable, relative phrasal plausibility. There is, however, no standardized reference from which to calculate the plausibility of the phrases used here. A plausibility judgement test was constructed to establish plausibility ratings for each phrase. Forty college aged subjects were asked to rate the randomised phrases on a scale of 1 - 5, according to 'how likely they were to hear or use the phrase in everyday conversation'. The total rating was calculated for each phrase. The member of each pair which scored most highly was rated most plausible.

[7]The materials were taken from personal searches and from corpora collected by Nakatani and Dukes (1977) and Lehiste (1960).

alternative reading *seal*), the second was such that the acoustic cues and lexical biases conflicted (listener hears *seal eyeing*, i.e. acoustic cues are commensurate with *seal eyeing* interpretation, but the lexical biases favour the alternative interpretation, i.e. *see* which is more frequent than *seal*).

Table 4-1: Experiment 1: Sample of Materials

Sample of Materials and Distractors		
	List A	***List B***
Materials	it sprays	its praise
	grey day	grade a
	an iceman	a niceman
Distractors	blue jar	glue jar
	run fast	run past
	old boots	old books

An equal number of materials from each experimental condition (cues and bias conspire versus cues and bias conflict) were divided to produce two listening conditions. Each listening condition contained stimuli with a combination of all independent variables; 13 early juncture stimuli and 13 late juncture stimuli; 13 of the tokens had frequent initial items, 13 had rare initial items; and 13 were plausible segmentations while 13 were less plausible. That is, frequency, plausibility and juncture position were counterbalanced across treatments. With certain stimuli this leads to an inevitable confound of lexical variables. Multiple Regression analysis is employed later to tease apart the effects of individual variables.

The materials were randomised such that the same order was maintained across listening conditions. For each item, listeners in one listening group received acoustic and bias information which conspire to give the correct interpretation, while the subjects in the other group get acoustic and bias information which conflict. A set of distractors was incorporated into each listening condition. These consisted of two word strings of similar length to the experimental stimuli but which differed in phonemic terms rather than in segmentation point (See Table 4-1).

Each list, along with distractors was recorded by a female Scots English speaker in one recording session using a Sony F1 Digital Audio Recording System in the recording studio of the Department of Linguistics, University of Edinburgh. A set of practice items was also recorded. The experimental tokens recorded are listed in Appendix A.

Note that the operational definition of "correct interpretation" of a phrase is that which corresponds to the speaker's interpretation of the string - the one prompted by the orthographical representation seen by the speaker. I did not digitally analyse the acoustic differences between the reading of each pair so any reference to lateness of point of juncture and meaning differences which arise are in accordance with the operational definition adopted.

4.6.5. Subjects

There were two subject groups: 28 normal subjects and 9 aphasics. Fourteen normal subjects were exposed to Condition 1 and 14 to Condition 2. Of these 28 normal subjects, 14 were age matched with the aphasics and were given the same stimuli conditions as their aphasic partner. This enabled an analysis of the results with subject type as an independent variable. Of the 9 aphasic individuals, 5 were tested twice, once in each Condition. A period of three months elapsed between each testing. The following listening configuration was adopted. Subjects are numbered A(phasic) 1-7, N(ormal) 1-21.

Condition 1		**Condition 2**	
A1a	N1a	A1a	N1b
A2a	N2a	A2a	N2b
A3a	N3a	A8a	N8a
A4a	N4a	A9a	N9a
A5a	N5a	A5a	N5b
A6a	N6a	A6a	N6b
A7a	N7a	A7a	N7b
	N8		N9
	N10		N11
	N12		N13
	N14		N15
	N16		N17
	N18		N19
	N20		N21

The aphasic group was not homogeneous but all suffered perceptual problems and each was analysed using the BDAE (Goodglass and Kaplan, 1972) or cognitive neuropsychologically motivated batteries (Kay et al., 1988, Franklin, 1989). The aphasic subjects profiles and linguistic assessments are provided in Tables 4-2, 4-3, and 4-4.

Table 4-2: Experiment 1: Aphasic Subject Profiles

Subject profiles						
Patient	***Sex***	***Age***	***Time Post Onset (months)***	***Aetiology***	***Occupation***	***Aphasia Type***
F I	M	72	10	Left CVA	Engineer	Fluent
E K	M	48	10	Left CVA	Builder	Fluent
J A	M	39	13	Head Injury	Barman	Anomic
J D	M	40	10	Head Injury	Electrician	Fluent
A L	M	62	12	Left CVA	Manager	Fluent
M S	F	60	12	Left CVA	Housewife	Fluent
E T	F	52	19	Left CVA	Housewife	Non-Fluent[8]
S W	F	29	09	Left CVA	Air Steward	Fluent
M B	M	70	14	Left CVA	Laborour	Fluent

The remaining subjects were examined using more traditional assessments such as the BDAE (Goodglass and Kaplan, 1972), and the W. A. B. (Kertesz, 1979).

4.6.6. Procedure

4.6.6.1. Pre-test

A visual lexical decision task was used to screen subjects for the auditory discrimination test. All of the words which comprised the test materials were used as tokens. Distractors were made by distorting one phoneme of each word by one or two phonetic features. These non-words were given a word-like orthographic representation which resulted in tokens such as *ikeman* from *iceman*, or *feep* from *keep*. Subjects who scored less than 85% were eliminated from the later experiment. This ensured that

[8]E. T. was variously classified as a Fluent and Non-fluent by clinicians. Her performance on the profiling and experimental tests did not differ from that of the other fluent aphasics in any important way.

Table 4-3: Experiment 1: Aphasic Subject Linguistic Profiles - Results of Auditory Perception tests.
N/T = not tested. Normal ranges have only been empirically validated for the CVC discrimination test. Mean = 0.86 (Franklin, 1989)

Aphasic Subject Linguistic Profiles					
Profiling Test	***F I***	***E K***	***J A***	***J D***	***A L***
CVC Auditory Discrimination	.84	.94	1	.81	.90
CVC Non-word Discrimination	N/T	N/T	1	.81	.85
Auditory Lexical Decision	.80	.91	.93	.85	.91
Visual Lexical Decision	N/T	N/T	N/T	N/T	.91
Word-Picture Matching	.66	.78	1	.93	.83
Word initial phonological segmentation	N/T	.87	N/T	N/T	.91
Auditory synonym matching	N/T	N/T	.92	N/T	.94

subjects taking part in the experiment proper had lexical knowledge of the experimental items and that their visual processing was not impaired.

4.6.6.2. Set induction procedure

Common to all the investigations which constitute the thesis, is the implementation of a rigorous "Set Induction Procedure". Because of problems inherent in working with linguistically impaired subjects, experimental procedures must be as self evident as possible. Any verbal instruction must be kept to a minimum or supplemented with demonstrative instruction. To counter the restrictions imposed on explaining procedural details, Blumstein et al. (1982) devised a "Set Induction Procedure". It relies on demonstration of the task as opposed to instructions for its execution. This procedure was adopted throughout the current research. In brief, the induction entailed

Table 4-4: Experiment 1: Aphasic subjects Linguistic Assessments

Aphasic Subject Linguistic Profiles - Summaries of Linguistic Assessments.	
Name	***Summary of linguistic skills***
M S	Low scores on "Palm tree and Pyramids" test, and lexical decision tasks. Exhibits perseveration. Previously had severe naming difficulties, now only mild.
E T	Residual comprehension disorder with predominant expressive problems. Telegraphic non-fluent speech style. Auditory perception impaired.
S W	Word finding and naming deficits. Comprehension levels recovering, auditory perception still impaired.
M B	Severe expressive and low-level perceptive difficulties. Functional comprehension very poor.

the investigator running through a simplified format of the required procedure with the subject. The experimenter then started the task giving the subject the correct response to the first five items, guiding the answer to a further five and continuing with the task, guiding answers where necessary, until the subject consistently responded correctly. The materials used in the set induction procedure were highly differentiated pairs which had all been correctly identified by a set of normal subjects. The preparation tape contained a further 10 utterances on which the aphasics practiced before starting the task proper.

4.6.6.3. Task proper: Experiment 1

Subjects were tested individually. They were visually presented with individual pairs of two- or occasionally three-word tokens. The pairs of visual tokens were laser printed in good quality large print[9]. The tokens consisted of the target item and its mate, the alternative interpretation of the string. Subjects were asked to read each token and then look away from the printed sheet to indicate that they were ready to listen to the recorded stimuli. They were then played a tape recorded phrase which matched one of the pair of printed stimuli. The recorded stimuli were presented using Portable

[9]Font: Helvetica, 30 point.

Morantz CP43 stereo cassette players and listening potential was optimised by delivering the aural stimuli through Revox 3100 headphones.

Subjects were then instructed to look at the printed pair again and indicate which matched the aural stimuli. This strategy of first presenting alternative visual matches to the auditory signal is a format typically employed in word discrimination tests and has the advantage of focusing the subject to a particular area of phonological space. The normal subjects were asked to circle their interpretation whereas the aphasics were instructed to point to their choice and the investigator then recorded their choice. Physical limitations presented by some of the aphasic subjects meant that the task was carried out in their place of therapy or their own home. All normal subjects were tested in quiet rooms.

4.7. Results

The overall response accuracy was examined first. Response accuracy was judged relative to the speaker's intended segmentation. Table 4-5 illustrates the number of correctly interpreted stimuli for aphasic and normal subjects. Normal subjects were significantly more accurate in their segmentation choices than aphasics, though neither subject group was able to judge consistently the tokens in a way which corresponded to the speaker's intended meaning. (Normal mean percentage correct response = 63%, aphasic mean = 53%). The difference in response pattern between aphasic and normal subjects was significant in a chi-square analysis ($\chi^2 = 8.48$, df = 1, $p < .01$). The same was true when only the matched normal and aphasics were used $\chi^2 = 10.45$, df = 1, $p < .01$. All further analyses used only data from the matched subjects.

Table 4-5: Percentage Correct Responses across Subject Groups

Correct Segmentations.		
	Normal	***Aphasic***
All Subjects	408 (63%)	196 (53%)
Matched Subjects	240 (65%)	196 (53%)

Separate analyses were conducted to judge the role of the independent variables : *lateness of juncture*, *frequency of initial word* and *plausibility* of alternate readings. All analyses employ the same data with materials divided in different ways for investigation of each independent variable. Figures 4-1, 4-2, 4-3 illustrate the resulting patterns. Chi-square analyses show that for all of the independent variables, the normal subjects responded correctly significantly more often than the aphasics.

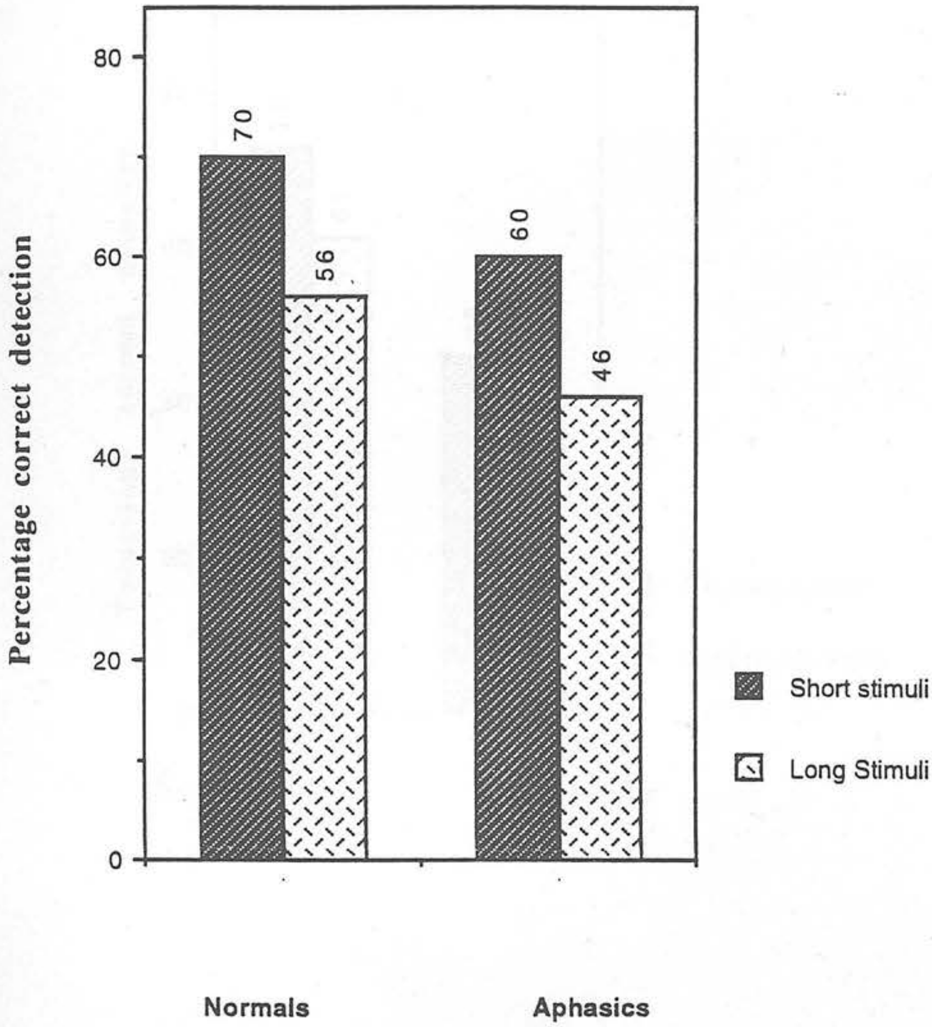
4.7.1. When lexical biases conspire with acoustic information

Both subject groups responded more accurately when the correct interpretations were supported by the bias in question than when there was a conflict with the bias: when a potential bias was corroborated by whatever acoustic cues were in the signal, correct segmentation was more likely compared with when the two were in opposition. There was an interaction between subject group and direction of bias: normal subjects could exploit the coincidence of bias and acoustic cues but when bias and acoustic cues conflicted they could ignore bias. Aphasics were less able to exploit both bias and acoustic cues when it was appropriate and were less able to ignore bias when it conflicted with acoustic cues. For each independent variable, when bias and acoustic material conspired, normal subjects segmented correctly more often than aphasics. The difference is reflected in chi-square analyses: (a) length bias $\chi^2 = 3.99$, (d.f) =1, $p <0.05$; (b) frequency bias $\chi^2 = 7.08$, (d.f)=1, $p <0.01$; (c) plausibility bias $\chi^2 = 6.32$, (d.f)=1, $p <0.02$. Direction of tendency was the same in both subject groups i.e. towards applying the bias.

4.7.2. When lexical biases conflict with acoustic information

When use of bias was inappropriate, that is, acoustic cues and biases conflict, the normals again segmented the signal correctly significantly more often than the aphasics. The difference between the normal and aphasic scores was significant for the length variable; $\chi^2 = 4.43$, (d.f.) = 1, $p < 0.05$; and the plausibility variable, $\chi^2 = 4.15$, (d.f.) = 1, $p < 0.05$. Although the difference in response was not significant for the frequency variable when the target word was *rare* ($\chi^2 = 1.27$, (d.f) = 1, $p = 1$) the same trend in response was observed. The aphasics' response pattern still tended to favour the segmentation supported by the bias: they could not ignore misleading bias

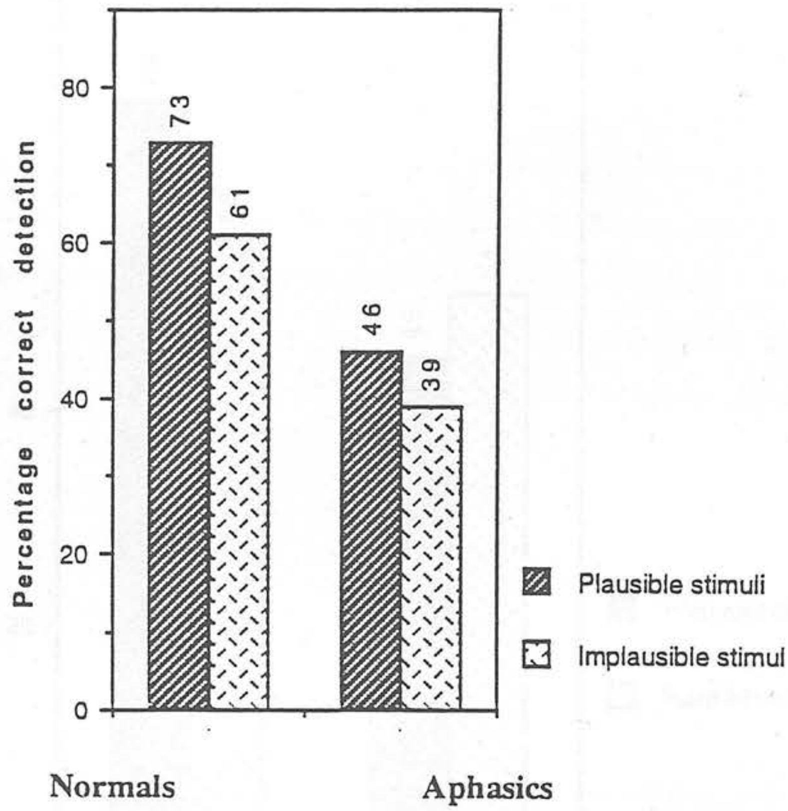
Figure 4-1: Normal and Aphasic response patterns to Long first word stimuli, and Short first word stimuli.



Raw Aphasic Data.
Number of Correct Identifications: by stimulus type

	Long	Short
Mean	6.7	7.2
Range	6	11
St. D.	2.8	1.7
Min	4	4
Max	10	15

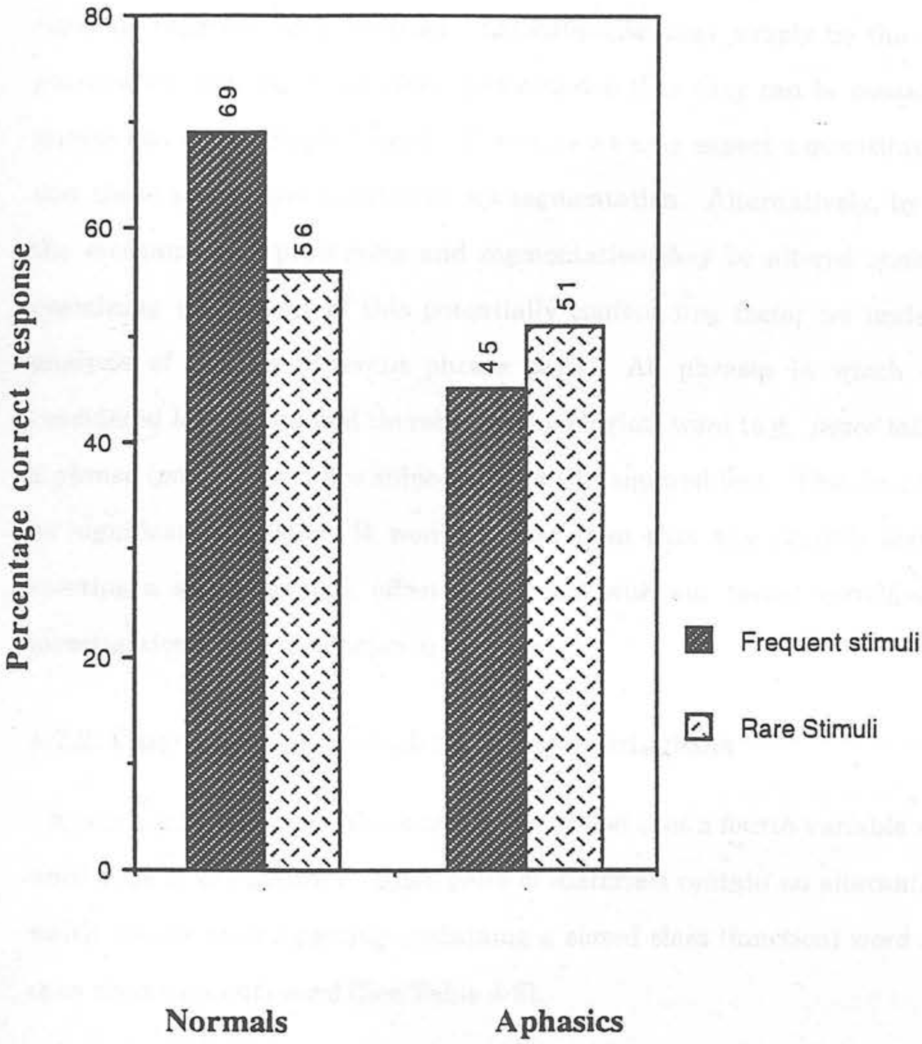
Figure 4-2: Normal and Aphasic response patterns to more plausible stimuli, and less plausible stimuli.



Raw Aphasic Subject Data.
Number of Correct Identifications: by stimulus type

	Plaus	Implaus
Mean	7.2	6.4
Range	13	9
St. D.	3.7	2.8
Min	2	1
Max	15	10

Figure 4-3: Normal and Aphasic response patterns to Frequent first word stimuli, and Rare first word stimuli.



Raw Aphasic Subject Data.
Number of Correct Identifications: by stimulus type.

	Freq	Rare
Mean	8	5.7
Range	6	11
St. D.	1.6	2.3
Min	4	3
Max	11	11

information. Both groups segmented less correctly when the bias and acoustic cues conflicted than when they conspired.

For the **plausibility** bias, it was noted that some of the phrases labelled as **plausible** could be regarded as lexicalised. Lexicalisation may simply be the result of extreme plausibility, that is, so plausible and common that they can be considered no longer a phrase but a phonological word. Therefore we may expect a quantitative change in the way these strings are considered for segmentation. Alternatively, by being lexicalised the mechanism of processing and segmentation may be altered qualitatively. Before examining the import of this potentially confounding factor we undertook a *post hoc* analysis of the five relevant phrase pairs. All phrases in which one partner was considered lexicalised and thereby, a phonological word (e.g. *peace talks*) and the other a phrase (*pea stalks*) were subjected to a Chi squared test. This small data set yielded no significant statistic. It would appear then that any possible lexicalisation is not exerting a strong enough effect to interact with our tested variables and no further investigation of the phenomenon was made.

4.7.3. Open- versus closed-class segmentations

A *post hoc* inspection of the materials revealed that a fourth variable was also testable; word class of competitors. Some pairs of materials contain an alternative segmentation which results in one parsing containing a closed class (function) word and the other an open class (content) word (See Table 4-6).

The literature presents conflicting evidence on the subject of whether aphasic processing differs from the norm with regards word class ((Bradley & Garrett, 1979) but *cf* (Gordon, 1983)).[10]. An analysis of items which varied in terms of word class of initial member was undertaken to establish whether the word class variable had any effect on the choice of segmentation. The lack of clear consensus in the literature makes predictions for fluent aphasics difficult. The claim that fluent aphasics are not among those who typically exhibit particular processing deficits with closed-class words, would predict that there would be no segmentation preference for the open-class items for the

[10]An account of the relevant literature is given in Chapter 8.

Table 4-6: Experiment 1: Stimuli pairs which contain class contrasts

Pairs with contrasting-class members	
OpenClass	***ClosedClass***
play taught	plate ought
two ran	tour an
see Mabel	seem able
Ice cream	I scream
iced ink	I stink
youth read	you thread

aphasic subjects in the current experiment. Other studies, however, imply that all aphasics have impaired processing of closed-class items (Gordon, 1983). If lexical items are assumed to be stored along with information about word-class, semantics, statistics of occurrence etc, then any general degradation of processing may lead to hindered processing for words which require activation of very complex feature arrays. This may result in an increased workload being attached to the processing of closed-class words. This latter theory supports the prediction that aphasic subjects would show a bias against recognising the closed-class segmentations.

There were only six pairs of stimuli where alternative segmentations contrasted in terms of word class. A chi-square analysis shows that aphasics show a trend towards favouring segmentations which leave an open class item, even when this is incorrect ($\chi^2 = 2.86$ (d.f.) = 1 $p < 0.1$) The aphasic response pattern follows that seen with the other variables: the aphasics parse the phrase in accordance with the bias regardless of whether the speaker intended this interpretation. The interaction of this variable with others cannot be fully examined because of the size of the data set but these initial findings suggest that it may be fruitful to study the role of closed class words in segmentation by fluent aphasics.

In sum, the results show that all three original independent variables (frequency, length, and plausibility) showed quantitatively different effects for aphasic and normal subjects. For all variables, normal subjects showed a stronger trend towards choosing the intended "correct" interpretation of the ambiguous string. Where it was appropriate to appeal to a bias, identification accuracy was augmented. That is, the tokens which are short-long in structure (e.g. *a notion*, as opposed to *an ocean*) or more plausible than the alternative lexical hypothesis (e.g. *seem able*, as opposed to *see mabel*) or have the most frequent first item (e.g. *see* in *see lying*, as opposed to *seal* in *seal eyeing*) are identified more accurately than those which are long-short, less plausible or have the rarer first item. Both aphasic and normal listener response patterns, at least in part, seem to reflect an advantage of the presence of two types of segmentation cues (acoustic and lexical bias) rather than just one. Although the effect obtains for all three biases, it must be considered whether or not it is possible to attribute any variation in segmentation choice to the use of each bias individually. Or is the bias effect cumulative? Or alternatively, is it the case that the effect of one bias is reliant on the presence of a further bias? The lexical characteristics of the materials are such that there are cases in which some of the independent variables are inevitably confounded. As the criteria for producing materials which are junctural minimal pairs are so limiting, it is difficult to construct sets which do not contain materials in which the effect of variables potentially overlap. The most noticeable example is the confound between frequency and length[11].

4.7.4. Multiple regression analysis

One method of establishing the unique contribution made by each variable is to use Multiple Regression Correlations. Multiple regression correlations were computed in an attempt to disconfound, in particular, the length and frequency variables and to establish which of the lexical variables (frequency of first item, plausibility of phrase, or length of first item) contributed most to the variance in the response patterns.

Multiple regression facilitates the examination of continuous, covarying variables in a meaningful way, allowing estimations of proportions of variance which are associated uniquely with each independent variable. This data analytic also provides a means to compare variables measured on nominal and ordinal scales with those measured on an

[11]This is a consequence of the correlation between word length and frequency (Zipf, 1935).

interval scale. Multiple regression is used here to tease out the influence of multiple independent variables on correct segmentation choice. The null hypothesis in multiple regression correlation predicts that with x_i partialled out (i.e. holding x_i constant) x_j, the independent variable under investigation, accounts for no Y variance in the population, where Y is the dependent variable.

When a set of independent variables have been identified they are assigned a place in a hierarchy determined by the principles of causal priority and research relevance. A hierarchical multiple regression analysis allows us to apportion significance of individual variables. Each variable is added to the analysis in the order determined by the hierarchy. We then measure the increase in the account of the variance (R^2) in the dependent variable. Significant increases reflect how useful the most recently added variable is in determining the way that the present set of independent variables predict the dependent variable. When a significant increase in account of variance is observed, the regression coefficients for each individual variable (β) indicate the unique contribution of that variable to the account of variance. Those with significant regression coefficients are assumed to be having an effect on predicting the dependent variables.

4.7.5. Normal response patterns

First I considered the simple univariate correlations between each of the independent variables - frequency, length and plausibility - and response accuracy. Significant correlations were found between the dependent variable and frequency, (r = .22 df(1, 362) p = <.01), length, (r = .15, df(1, 362), p = < .01), and plausibility (r = .05, df(1, 362), p = < .01). These results reflect the earlier chi-square outcome: the appropriate use of biases by listeners facilitates choice of correct segmentation. The correlations also reflect the order of relative contribution made by each variable. In addition, the correlation matrix reveals the relationships among the independent variables themselves. The materials here are typical of the lexicon in general in terms of the relationship between length and frequency; the length and frequency of a phrase's first word are highly correlated ((r = .77, df(1, 362), p = <.01). Length and plausibility, and frequency and plausibility are not significantly correlated.

When the variables are analysed together, the unique contribution of each variable can be assessed. A hierarchical analysis yields data on the effect of partialling out combinations of variables. The first question addressed was whether the confounding of frequency and length is affecting the unique contribution made by each variable individually. Considering frequency and length partialled out together provides the first insight into this. The addition of the frequency variable to the equation initially only containing the length-segmentation choice information, shows a significant increase in the amount of variance accounted for ($R^2 = 0.05$, $F(2, 361) = 3.66$, $p = < 0.05$). More importantly, inspection of the standardised regression coefficients show that the only variable responsible for this increase is frequency ($\beta = 0.26$, $p < 0.01$). For the normal subjects the variance accounted for by the length variable would seem to have been almost entirely reliant on its relationship with frequency. It does not independently contribute to the account of variance in the results. This disconfirms the prediction supplied by TRACE.

It was also of interest to know whether plausibility was contributing to the overall account of variance. When this third bias is subsequently partialled out, there is no significant increase in the total account of variation. ($R^2 = 0.05$, $F(3, 360) = 0$, $p = 1$). A glance at the standardised regression coefficients again shows that only frequency is uniquely responsible for any variance accounted for ($\beta = 0.26$, $p < 0.01$). This result shows that although plausibility and length seem to predict the choice of segmentation, their doing so is almost entirely dependent on their relationship with the frequency variable and the influence frequency is exerting on other variables which are also correlated with plausibility and length. The fact that the standardised regression coefficient for frequency increases when length is partialled out, suggests that length is in fact suppressing the effect of frequency.

4.7.6. Aphasic response patterns

A very similar picture emerges from the analysis of the aphasic data. The simple correlations show that length ($r = .10$, df(1, 361), $p = <.01$) frequency , ($r = .16$, df(1, 362), $p = <.01$) and plausibility ($r = .09$, df(1, 361), $p = <.01$), are all correlated with aphasic segmentation choice[12]. When an analogous hierarchical analysis to that conducted on the normal data was performed using the aphasic results, a similar pattern emerged. When frequency is partialled out with length, the amount of variance accounted for increases significantly ($R^2 = 0.027$, $F(2, 360) = 3.30$, $p = < 0.05$). The variance accounted for is again, almost entirely attributable to frequency ($\beta = 0.21$, $p < 0.01$). The variance accounted for by length again appears to have been dependent on its relationship with frequency. When plausibility is added to the equation, a small increase in the account of total variance is found. This, however is not significant ($R^2 = 0.03$, $F(3, 359) = 0.36$, $p = 1$). Of the three variables, only frequency is making a significant contribution ($\beta = 0.20$, $p < 0.01$). Although still robust, the standardised regression coefficient for frequency has dropped slightly. This suggests that the role of plausibility is marginally more salient for the aphasics than for normals. In the main, however, the aphasic results qualitatively resemble those for the matched normals; the effect of the length bias and plausibility biases are largely the result of their relationship with frequency.

In brief, frequency is the only salient predictor of normal subject responses. Frequency is also a significant predictor of aphasic responses but is less predictive of these than the normal data. In addition, the aphasic responses are partly predicted by the plausibility rating of the phrase. Aphasic and normal results differ in quantitative terms; the slope or intercept of the regression lines differs significantly between subject groups at a probability of $p > 0.05$. This echos the chi-square analyses reported earlier which showed that normal subjects are significantly more successful at identifying the target word than aphasics. Furthermore, the set of predictor variables analysed (frequency, plausibility and length) account for more of the variance in the aphasic responses than in the normal responses.

[12]As the materials used were the same across subject groups, the correlations between independent variables are the same in this analysis as those reported in the normal data section.

4.7.7. Error Analysis

A further striking difference between the normal and aphasic samples emerges from analysis of the identification of filler items. From the normal sample, only one subject misinterpreted one filler stimulus. Five of the nine aphasics wrongly identified between 2 and 8 filler items. It was necessary therefore to establish whether the aphasic performance on the segmentation task reflects a straight deficit in phonological perception of the same sort which would lead to problems in phoneme discrimination. Recall that the filler items differed by 1, 2 or 3 features on one phoneme of one word in the token phrase (note that there is one exception to this in that the *'cold ghost - gold coast'* dyad has two such differences). If a subject shows the same difficulty discriminating between pairs which differ in phoneme features as those differing in segmentation point, we could propose that the performances in the two tasks are related in some way. A Pearson product correlation between the respective error rates for filler and test items was not significant (r = .78, (d.f.) = 4. $p > 1$). This same result with a more representative selection of materials would suggest that the results of the segmentation task reflect more complex dysfunctioning than solely a deficit in phonemic perception.

4.8. Discussion

The results of this study affirm that for both aphasics and normals, acoustic information is not sufficiently specified to indicate place of juncture reliably: neither group could consistently identify the speaker's intended segmentation. Furthermore, both groups are more successful when the cues and biases conspire than when they conflict. This suggests that listeners are able to use biases to facilitate segmentation when acoustic cues are insufficient to identify words. In both the "conspire" and "conflict" conditions normals were significantly better than aphasics at correctly segmenting the materials. Of the two conditions, the "conflict" condition elicited the greatest difference in aphasic and normal performance: normals had a greater advantage over aphasics in the "conflict" condition. Of the biases, the frequency bias is found to be that which makes a unique contribution to segmentation choice for both subject groups. It is only with the aphasic subjects that plausibility exerts an independent effect on choice of segmentation.

4.8.1. Interpretation of normal data

Let us first consider the failure of the normal subjects to segment the signal with 100% accuracy. This lends support to some of the Nakatani and Dukes (1977) findings. Their materials were extensively manipulated and could be criticised for being highly unnatural sounding tokens. The present results, however, which were obtained using unmanipulated materials, corroborate their main finding that acoustic cues to segmentation are of limited use. It should be noted, however, that both the Nakatani and Dukes study and the present investigation involved presentation of materials in isolation. It is possible that in running speech additional prosodic or phonetic cues augment the difference between the two interpretations and aid correct identification. There are, however, no findings to date which could confirm or disprove this hypothesis.

One alternative explanation of the data might be found by exploring the type of variation which occurs at the point of segmentation. Work by Marslen-Wilson and colleagues (Lahiri & Marslen-Wilson, 1991, Marslen-Wilson, 1992, Gaskell & Marslen-Wilson., 1993, Marslen-Wilson & Gaskell., 1992) has demonstrated that the lexical access system is strongly influenced by bottom-up information but that it is tolerant of mismatch between input and representation if that distortion is legal within the presented context. For example [lim] in *leam bacon* is processed as efficiently as if the utterance had been [lin]. Although the distortions given as examples here lead to the production of 'non-words' (*leam*) and the differences are at the phonological level, they do imply that the the processor has a mechanism for entertaining multiple hypotheses which minimally differ from the input. In the current experimental materials, the acoustic variation which differentiates the two segmentations (e.g. *seal eyeing* and *see lying*) could be seen as contextually legal variants of the alternative parse. That is, when the listener is hearing *seal eyeing* they are also hearing a contextually legal variant of *see lying*. This might imply that the acoustics would promote equal activation of both readings and might explain why acoustic information at this level seems to be of minimal use in distinguishing between intended parses.

Next let us explore the implications of the first result (the failure to segment consistently correctly) in tandem with the second result - the advantage the normal (and aphasics) subjects afford from the conspiracy of acoustic information and lexical biases.

There are two viable explanations for why (a) the correct segmentation is not always accomplished while (b) those cases where it is more often successfully completed, are those in which acoustic cues and biases co-operate. The first explanation would be that listeners use only one source of cuing (either cues or biases) but that the use of only one source is not sufficient for successful segmentation. If the first hypothesis were correct, there would be no appreciable difference in response accuracy whether the acoustic cues and biases were commensurate or conflicting. Results would consistently reflect adherence to one strategy. That is, the responses would be always commensurate with the acoustic cues and therefore always right when the cues were clear enough, or always consistent with the bias; that is, the most segmentation with the most frequent first word would always be chosen. Alternatively, it could be that both cues and biases are used but that accuracy is hampered when different types of cues conflict. This would provide results in which greater accuracy was achieved when biases and cues conspired than where they conflicted.

Clearly the second hypothesis is more compatible with the normal data. Recall that there are two utterance conditions - (1) Cues and biases conspiring to give the intended interpretation, and (2) cues and biases conflicting - each elicits a radically different response pattern from normals. For each bias, accuracy is of the order of 70% in condition (1) and 55% in condition (2). This suggests that normal subjects use some acoustic information. The fact that normals interpret erroneously when acoustic cues do not tally with biases could also imply that biases are having a significantly competitive influence.

Recall that for the normal responses, when the effects of the biases were analysed together, only frequency was found to make an independent contribution to the segmentation choice. Marslen-Wilson (1990) reports that, in the processing of speech, at points of ambiguity the most frequent hypotheses are afforded an advantage. It would seem from the current data that this frequency effect is operational when the problem is one of junctural ambiguity. In terms of the Cohort model (Marslen-Wilson, 1992) of the competing hypotheses activated on the strength of bottom-up activation, if ambiguity remains after the input of all acoustic information, it is the frequency of the competitors which determines which candidate will be recognised. The normal subjects do not appear to invoke the plausibility of the phrase in their recognition process.

The fact that length has no independent effect on the resolution of the segmentation ambiguity has implications for the interpretations of TRACE simulations. Recall that the TRACE simulation results (Frauenfelder, 1990) predicted parsing to give late juncture by segmenting to leave a long word first parse. These results were obtained from an implementation of TRACE which did not incorporate frequency effects. The present data show that frequency has an overriding effect on any independent length preferences. These findings suggest that the length effect will not emerge independently because of the close correlation in the lexicon between length and frequency. Further, because of this correlation, if any length prediction were to be made it would be more parsimonious to predict the choosing of the shorter word first parse. Implementations of TRACE which are to reflect more realistically the current behavioural findings, would have to tune down the between-word competition effects and tune up frequency effects.

4.8.2. Interpretation of aphasic data

The aphasic subjects showed impaired lexical segmentation of the strings presented to them. This has implications for Blumstein's finding that for fluent (Wernicke's) aphasics, auditory perception difficulties did not map successfully onto comprehension deficits. The segmentation data show that the auditory deficits of these fluent aphasics do translate into difficulty in integrating multiple cues for segmentation and lexical access. As the current study captures performance at an earlier stage of processing than did Blumstein, I would argue that this is a more direct measure of how auditory perception deficits affect the 'intermediate' stages of comprehension.

The data show that although the aphasics were significantly less accurate in their responses than the normals, in most respects this difference was a quantitative one. Aphasics fared worst in the same conditions in which the normal subjects performed badly. This implies that the aphasics are using essentially the same mechanism for processing the segmentation information as the normals.

The difference in the correct interpretation of materials between the "conspire" and the "conflict" conditions was much greater for aphasics than it was for the non-impaired subjects. The aphasic listeners identified stimuli less accurately in the "conflict" condition. In effect, the aphasics seemed to favour the bias-suggested interpretation no matter what the acoustic information cued for. This suggests that the aphasics derive minimal use of the acoustic junctural information which causes them to display an inflexible response style. In the "conspire" condition, on the other hand, the aphasics seem to use a bias to complement other sensory input. The data show, however, that their ability to do so is significantly below normal efficiency. Whereas the normal subjects can, to a large degree, integrate acoustic and bias information, aphasics find this difficult.

The bias which best predicts the aphasic segmentation choice is the same as that used by the normals: frequency. When the acoustic information is insufficient to specify segmentation, the most frequent of the competing hypotheses reaches recognition. In terms of the Cohort model (Marslen-Wilson, 1987), the more frequent competitor achieves fast initial activation and maintains an activational advantage over its less frequent competitors. For the normal subjects we have seen that when the target segmentation is in fact the one containing the less frequent competitor, the acoustic information occasionally fails to sufficiently specify for this and the erroneous (most frequent) competitor is chosen. The aphasics appear to be less able still to use the acoustic information to reach the intended segmentation. This means that the frequent (and erroneous) hypothesis does not receive disconfirmatory bottom-up inhibition more often than is the case for normals. We could infer that in such a situation the lexical candidates which are activated to high levels, i.e. those which are favoured by the frequency bias, never decay below the levels reached by competitors because the aphasic subject never receives enough sensory input to favour the intended candidate or disconfirm the erroneous-but-bias-favoured one. We can hypothesise then, that where acoustic input is perceptually ambiguous, aphasics show *exaggerated* frequency effects because they are unable to integrate these with the limited acoustic information which they have access to[13].

In addition to frequency, the aphasics' segmentation choice is also partially predicted by the plausibility of the alternative phrases. This may reflect a metalinguistic strategy which the aphasics adopt when no segmentation is favoured. The more plausible

[13]The issue of frequency effects is taken up more fully in Chapter 6 & 7.

alternatives may provide a more solid representation which the aphasics could maintain more easily. When bottom-up information fails to differentiate the alternatives the plausible representations would be more readily sustained. It is not possible to tell from this data whether this is the case. Even if the aphasic performance does contain an element of metalinguistic processing, it is improbable that the aphasics' segmentation strategy is conducted entirely at this level. The presence of a frequency effect (which is a well attested non-conscious effect) in the aphasic performance, renders arguments which support a purely metalinguistic explanation, less viable. The present data are most compatible with the notion that for the most part, aphasics are using the same processes as normal subjects to segment the speech signal. But, because of their failure to integrate the acoustic and frequency bias information, the aphasics do not resolve the competition between alternative candidates. It is at this point that their processing diverges from normal and they enlist metalinguistic biases such as plausibility to establish finally the segmentation.

4.8.3. Summary Conclusions

These results confirm the predictions of interactive paradigms which posit that for normal and aphasic listeners, acoustic information is not of paramount importance and that segmentation is largely accomplished without reference to the fine-grained acoustic input. The data also show that even when acoustic material is limited or inadequately perceived (as it is for aphasics), segmentation is accomplished with reference to the frequency bias rather than by random choice of interpretation. Aphasics also afford plausible alternatives an advantage in cases of persistent ambiguity. The fact that the frequency bias is still operational even after cerebral damage implies its resistance to impairment. I posit that this reflects the status of the lexical biases as being fundamental and distributed aspects of the language processor.

Chapter 5
Use of Metrical Prosodic Cues in Segmentation

5.1. Introduction

In this chapter I focus on the question of whether fluent aphasics use the same prosodic strategy as that purportedly used by normal listeners as a cue to initiate lexical access. I will first outline the theory which posits the use of metrical prosody in segmentation of continuous speech. Then I will examine the motivation for hypothesising that prosodic cues are still accessible post morbidity. After discussing experimental evidence for use of such a strategy by normal listeners, I will describe an investigation with ten fluent aphasics. Finally I will consider what implications their apparent retention of the strategy has for models of normal and pathological speech perception.

Fluent aphasics typically present with *specifically* impaired auditory perception and, even in the mildest manifestation of fluent aphasia, a *general* degradation of perceptual processing is usually evident. Often, however, the *communicative deficit* is not as extensive as one might predict given the complexity of the information processing task and the severity of their specific perception deficits. It is relevant therefore to consider how people with such impairments compute the complex array of information present in the speech stream in order to initiate lexical access for word recognition. Is the segmentation of the speech stream hampered by the specific and general deficits? Or is the location of the starts of words non-problematic for aphasic listeners? In this chapter I consider the hypothesis that aphasics retain a sensitivity to metrical prosody and that they utilise this information to aid word onset detection for lexical access.

5.2. Motivation for Investigating the Use of Metrical Prosody

The motivation for looking at metrical prosody, in particular, comes partly from observation of speech therapeutic practice; speech rate is slowed and emphatic stress is employed to aid comprehension. The literature also provides accounts consonant with this observation (Blumstein, 1985, Albert, 1974, Poeck, 1981). In part, such speaking strategies stem from the therapists implicit assumption that finding the optimum place to start lexical access is not as easily targeted by fluent aphasics as it is by normal listeners. Blumstein et al. (1985) undertook a detailed study of the effects of manipulation of several acoustic parameters of the speech signal to see if any aspects of it aided word boundary detection and/or auditory comprehension. The major finding was that certain manipulations of the speech signal (in particular insertion of inter-word silences) impaired word detection rates among those subjects with better comprehension skills[1]. For the Wernicke's aphasics, the only condition in which improved word detection was found, was when a gap was inserted to highlight word boundaries at syntactically important points in the sentence. Even in these cases it was concluded that, although such a manipulation afforded a small degree of improvement to auditory language comprehension, the advantage did not translate into improvement in sentence processing. The reason proposed for this was an inability to integrate the information accrued. In addition, it is noticeable that the acoustic manipulations of the target materials resulted in unnatural prosody. Any advantage gained may have been to the detriment of the availability of any prosodic aids to segmentation.

One further interpretation of this change in speech rate is that it decreases cognitive load by reducing the amount of information stored in short term memory. It is contentious whether this would be the result of such action: even if slowing the speech rate decreases the rate of entry into the short term memory, it could be argued cognitive strain may be increased because of the need to store information for longer periods in short term memory for parsing to be possible. In the current chapter I propose to explore the possibility that this strategy of emphasising stress is an extension of the behaviour adopted by normal speakers when listening conditions are perceived to be

[1]Comprehension was graded using the Boston Diagnostic Aphasia Examination (Goodglass and Kaplan, 1972).

difficult. This is discussed in section 5.5. Before examining in detail the use of metrical stress in normal lexical segmentation, let us examine the general abilities of fluent aphasics to process prosodic information in general.

5.3. Manipulation of prosody by fluent aphasics

The left hemisphere plays an active role in the processing of linguistically implicated stress. Damage to the left hemisphere limits the utilisation of prosody in general but not as significantly as when the right hemisphere is damaged[2] (Blumstein & Goodglass, 1972).

5.3.1. Production of prosody

Wernicke's (fluent) aphasics have been shown to produce some non-normal speech prosody (Danley et al., 1983). In normal processing fundamental frequency peaks decline as an utterance progresses. Danley et al. reported that mildly and moderately impaired Wernicke's aphasics showed normal F0 declination. For many of the more severe patients, normal declination only occurred in shorter utterances. Danley et al. suggested that all but the most impaired Wernicke's aphasics were manipulating the F0 starting value so that longer sentences started with a higher peak. They propose that this reflects the Wernicke's subjects ability to integrate sentence length and declination slope requirements. Other abnormal F0 features include failure to use fundamental frequency to indicate differences between syntactic boundaries. In general, Wernicke's produced normal F0 attributes when they indicated global features (such as sentence length) but abnormal patterns when they corresponded to syntactic variables. None of these impairments are of the magnitude presented by Broca's aphasics, but fluent aphasic production of prosody was often impaired compared to normal performance.

[2]See Emmorey, (1987) discussed below for data at variance with this general claim.

5.3.2. Perception of Lexical Prosody

Perception of word stress by left brain damaged (LBD) aphasics has been studied mainly with regard to lexical stress. Given the role widely ascribed to the right hemisphere as processor of musical pitch (Schulhoff & Goodglass, 1969) and affective prosody (Ross, 1981), it has been hypothesised that linguistic prosodic information is also instantiated there. There is some evidence that patients with right brain damage (RBD) are more impaired in discriminating and naming emotional tone than their left brain damaged counterparts (Tucker et al., 1977). The picture regarding use of linguistically implicated pitch, tone or stress is, however, less clear. Van Lancker and Fromkin, (1973) concluded that "pitch discrimination is lateralised to the left hemisphere when the pitch differences are linguistically processed". This assertion has formed the basis for much subsequent research.

Baum et al. (1982) found that LBD "Broca's" aphasics were significantly worse than normals at using frequency duration and intensity (which are correlates of lexical stress), to disambiguate otherwise homonymous utterances. Severity of impairment correlated with difficulty in using lexical stress. Blumstein and Goodglass, (1972) report a different performance pattern using similar materials, but in this instance, where stress patterns differentiated nouns from verbs *transpórt* (v) vs *tránsport* (n). They suggest that left hemisphere damage does not impair prosodic perception. Both fluent and non-fluent subjects scored worse than normal controls, but the majority of errors were attributable to random factors and neither aphasic group's performance was attributable to impaired stress processing. No significant difference was reported between aphasic subgroups, either in quantity of errors or in type of word eliciting error. All groups (including normals) exhibited a hierarchy of preference; nouns were more successfully identified than verbs or adjective/noun phrases. RBD subjects, on the other hand showed impaired discrimination of prosodically differentiated noun compounds and noun-phrases such as *bláckboard vs blackbóard* (Weintraub et al., 1981).

None of the above studies made direct comparison between those with damage to the right hemisphere and those with left hemisphere impairments. Emmorey (Emmorey, 1987), however, tested RBD and fluent and non-fluent LBD aphasics. The materials used were modified from Blumstein & Goodglass's (1972) set. Subjects were required to match auditory stimuli to pictures. Production was also analysed. In the perception tests, the fluent aphasics' performance was significantly worse than that of normals, (though not as impaired as the non-fluent performance). RBD patients' performed almost normally. Emmorey concluded that the left hemisphere was implicated in linguistic prosody processing and that comprehension of lexical stress is impaired in LBD aphasics. These results are at variance with those of both Weintraub and Blumstein. Emmorey suggests that the peculiarities of Weintraub's small stimulus set, may have accounted for many of the errors made. Emmorey goes on to argue that the discrepancy between her results and those of Blumstein & Goodglass, is because of the errors attributed to random factors. Emmorey implies that many of the errors which were discarded as phonological perception errors may have masked additional errors due to stress misperception. She argues that when the materials are modified and simplified the random errors are eliminated and stress misperception emerges. Lexical stress does therefore not appear to function to full capacity in LBD patients, whether this is because of a damaged stress processor or an inability to integrate the use of stress and phonology. Blumstein's findings would support the latter model.

The dichotic listening paradigm has also been used to look at relative hemispheric involvement in speech prosody processing (Behrens, 1985). In normal listeners a definite right ear advantage was found (Behrens, 1985). This would seem to affirm the view that the left hemisphere is involved in prosodic processing. When the same materials were passed through a low-pass filter to reduce phonetic and, therefore, also semantic information, a slight trend towards left ear advantage was found. When subjects were asked to identify stress patterns of nonsense words and were given stress and phonetic but not semantic information, a non-significant left ear advantage was recorded. This set of data implies that as stimuli become less linguistically meaningful and the role of stress becomes less linguistic (as in the low pass filter and nonsense scenarios) the the role of the left hemisphere becomes less crucial, rendering left brain damage less catastrophic for such a task.

5.3.3. Perception of Emphatic Stress

Emphatic stress has also been implicated in the comprehension impairments of aphasics. Again, their is little concordance in views on whether aphasics retain the capacity to process the suprasegmental correlates of emphatic stress. Several studies report comprehension of passages improves when target elements are emphasised (Pashek & Brookshire, 1982, Kimelman & McNeil, 1987). When the emphasised target was a closed-class item, however, emphatic stress did not assist comprehension in Broca's aphasics (Baum et al., 1982). In addition, comprehension was not facilitated when the prosodic pattern of the utterance was held neutral and the stress of the target word alone was manipulated (Kimelman, 1991). The materials produced in this manner are arguably sufficiently bizarre that normal use of prosody is abandoned, bringing the validity of the results into question. If the results are valid, they imply the aphasic used prosodic information from an extended portion of an utterance in the processing of emphasised words. They also suggest that, while being successful at using the prosodic cues leading up to stressed words (contextual information), the aphasic is not sensitive to this kind of stress information present at the word level. It is also not made clear whether normal subjects also follow this pattern of sensitivity.

5.3.4. Summary

In sum, of left hemisphere damaged patients, fluent aphasics produce more normal prosody that their non-fluent counterparts. They also perform better than non-fluent aphasics in comprehension when this is dependent on the processing of prosody (Emmorey, 1987). Fluent aphasics can, in the main, manipulate fundamental frequency values to suit utterance length (Danley & Shapiro, 1982). This suggests that they retain the ability to integrate prosodic and higher level linguistic information (Danley et al., 1983). Their general processing of prosodic information is, however, often less efficient than that of normal speakers and listeners. The crucial predictor of impaired prosodic processing in LBD aphasics is the linguistic role played by the prosody the more linguistically relevant, the more that damage to the left hemisphere is likely to affect its processing. Prosody impairments associated with LBD are often presumed to lie at the stage of integration of prosody and other linguistic information rather than manipulation of prosody *per se*.

The prosodic information to be considered in the current investigation is metrical prosody. Unlike lexical prosody it does not differentiate between phonologically identical words. Furthermore, while lexical stress utilises a multi-tiered stress hierarchy, metrical prosody uses a binary stress opposition. Metrical prosody maintains the rhythm of stress timed languages. As metrical prosody is apparently relevant for word boundary alignment, and most LBD aphasics have not been shown to lose functional knowledge of metrical prosody, I predict that sensitivity to metrical prosody is maintained and persists as a cue to segmentation.

5.4. Use of Prosody for segmentation

5.4.1. The Metrical Segmentation Strategy in English

It has been claimed that prosody has a role in segmentation in that features of the prosodic profile of a language can be used as cues to segmentation. The segmentation strategy proposed for stress timed languages like English is the Metrical Segmentation Strategy (MSS) (Cutler & Norris, 1988). This is essentially a mechanism which encourages triggering of lexical access attempts when strong syllables are perceived[3]. It predicts that whenever a strong syllable is detected by the processor, lexical access is attempted. The original instantiation of the MSS theory (1988) predicted that if a strong syllable is present where there is no intentional word onset, all other things being equal, a lexical access attempt would be made but to the temporary detriment of the recognition of the words in that stream. This prediction was tested by Cutler & Norris (1988).

Using nonsense materials which contained real words they found that the target **mint** when followed by a strong syllable (**mint**ayve) was recognised more slowly than when followed by a weak syllable (**mint**ef). Cutler proposed that the delay occurred when the listener erroneously initiated a new lexical access attempt for the strong syllable in the suffix. Thus, during processing, the string is temporarily analysed as **min-t**ayve. No such analysis arises with the weak syllable suffix. The delay results from analysis of

[3]The MSS, and the present discussion and investigation of it, assume a definition of metrical prosody in which the prosodic dichotomy is labelled as strong and weak. The definition of a syllable as being strong or weak is not made on the basis of independent acoustic features but rather on "(the) *relative* prominence of the syllable's prosodic structure" (Ladd & Cutler, 1983)(my italics).

the word counter to the demands of the experiment (i.e. analysing the word as *min-tayve*, rather than *mint-ayve*) which necessitates reanalysis to recognise the target word **mint**.

5.5. Segmenting in difficult listening conditions

Further empirical data support the view that metrical prosody plays a role in segmentation. When normal listeners are asked to parse speech in difficult listening conditions, erroneous boundary insertion is significantly more common before strong syllables than in weak syllables (Butterfield & Cutler, 1988). For instance, listeners were more likely to interpret strings like *"Take it internally at breakfast"* wrongly as *Take it in turns to eat breakfast* than they were to interpret wrongly *in turns* as *interns* or *internally*. That is they would erroneously segment speech to give a strong initial syllable more often than they would give an erroneous weak initial syllable. In other words, *listeners* segment the speech stream to give parses with word boundaries prior to *strong* syllables (66% of the time) regardless of whether this is concomitant with the speakers' intention (Butterfield & Cutler, 1988).

In deliberately clear speech, speakers produce pauses at word boundaries (Picheny et al., 1986) though these pauses are typically shorter than the 250ms claimed to be the threshold duration for defining a pause (Grosjean, 1980). Investigation of durational changes in clear speech yields data which are equally supportive of the notion that the strong syllable has a privileged function in the processing of stress-timed languages. Cutler and Butterfield's (1989) study revealed a marked tendency for the speaker to emphasise the boundaries before *weak* syllables. In deliberately clear utterances, speakers paused before both strong and weak syllables. In emphatic versions of utterances, durations of pre-boundary syllables before weak syllables are greater (compared to baseline[4]). Similar syllables before strong syllables are not lengthened in comparison to those in baseline utterances. The boundaries preceding weak syllables were significantly more often and more clearly marked than those before strong syllables.

[4]Where baseline is the utterance when the speaker is not trying to speak clearly.

Cutler and Butterfield (1989) claim that speakers implicitly assume that listeners find *weak* initial syllables more difficult to detect and therefore give more additional emphasis to *weak* syllables than they do for *strong* initial syllables. It is argued that this augments the perceptual saliency of boundaries which are implicitly regarded as problematic (Cultler et al., 989b). Taken together, the two Cutler and Butterfield (1988, 1989) studies suggest that interlocutors perform stylised manipulations of prosody to facilitate speech recognition.

Patterns of "Slips of the ear" also typically concur with the notion that stress patterns are used to aid recognition. In their analysis of a large corpus of spontaneous perception errors, Bond and Garnes' (1980) propose that the normal listener utilises a set of heuristics. One, based on the observation that in the majority of mishearings intonation and stress patterns are maintained, is couched as: "Pay attention to Stress and Intonation Patterns". Another, based on the finding that few stressed vowels were misperceived, is: "Pay attention to Stressed vowels".

5.5.1. Cross-linguistic studies of prosody in segmentation

The use of metrical stress as a trigger to lexical access attempts is not claimed to be universal. Cutler & Norris (1988) imply, however, that it is generalisable to all stress-timed languages. Data from stress-timed languages other than English do not unequivocally support for this view. Quené and Smits (1992) failed to replicate the MSS effect in Dutch. They quantified metrical strength in terms of syllable accentuation and phonological vowel length but found that manipulating these features (either independently or together) did not affect word segmentation or lexical access. Quené and Smits suggest that the reason for the failure may lie in the different relation between vowel quality and metrical structure in Dutch and English. In English, metrical structure and nuclear vowel reduction are interdependent, in Dutch this is not so. The investigators propose that English listeners detect differences in vowel quality, use this to retrieve metrical structure, and show a segmentation effect because of this. Because no independent vowel length effect is found in Dutch, they propose that vowel length, although important, is not the only relevant factor and they suggest that Dutch listeners "rely on other (yet unknown) phonetic cues to the same end" (pp 215). These data could only support a weak version of the MSS which did not ascribe sole control over lexical access initiation to metrical prosody.

Other languages are reported to have analogous but different segmentation strategies which reflect the prosodic pattern of the language in question. Norris (1985) suggests that the MSS is a manifestation of a mechanism which is common for all languages but which is triggered by different prosodic elements in each language and that the trigger used in any given language reflect statistically robust properties of the language in question. Cross-linguistic behavioural data from syllable and mora timed languages have been shown to support this claim.

In syllable-timed languages such as French, there is evidence that the syllable is the trigger to lexical access attempts. In syllable monitoring tasks, subjects more quickly spot targets which correspond to whole syllables than when they correspond to sequences more or less than a syllable in length (Mehler, 1981, Mehler et al., 1981). For example, Mehler et al. found that the target sequence /ba/ was spotted more quickly in stimuli which had a syllable structure in which /ba/ formed a complete syllable (e.g. *balance*) than when it corresponded to only part of the stimulus's first syllable (e.g. *balcon*). When the target is /bal/, the opposite stimuli promote faster reaction time: /bal/ is found quickest in *balcon* as it corresponds to the whole of the first syllable. Mehler claimed that when the target sequence corresponds to a complete syllable processing is less complex which allows faster reaction times. Similarly, in mora-timed languages like Japanese, it appears that the salient trigger for lexical access is the onset of a mora (Otake et al., 1993).

Cross-language studies provide an additional insight into the role played by these segmentation phenomena in processing (Cutler et al., 1983, Cutler, 1986, Cutler et al., 1992). When English speakers listen to French materials like those described above, they showed no difference in their detection times of /ba/ in *balance* and *balcon*. When French speakers listened to English stimuli, however, they detected the target sequences in accordance with the strategy they had used for the French stimuli; they detected /ba/ better in *balance* which has a CV[C] syllable structure than in *balcony* which has a CVC structure[5]. The English speakers on the other hand, did not evince a

[5]Words like *balance* in English are assumed to be ambisyllabic (Anderson & Jones, 1974), that is the /l/ belongs to both syllables. For this reason a syllabic segmentation strategy would be of limited use for English. In the Cutler et al. experiment ambisyllabic words were deliberately used in contrast with words which have clearer syllable boundaries like *bal.cony*.

faster response to target stimuli as a function of the syllabic structure. English speakers did not respond faster or more accurately when the target syllable matched the stimulus syllable structure. This was true when the stimuli were French or English words. The French subjects always responded faster to target syllables when they matched a complete syllable in the stimulus word whether that word was English or French. This prompted Cutler et al. to conclude that the French syllabification strategy is a characteristic of the listeners rather than the language itself. Later work has suggested that this claim is generalisable to the MSS: that listeners whose language is stress-timed, will use a metrical strategy is segmentation, regardless of the prosodic timing in the heard language. When bilingual French/English speakers (with near-native abilities in both languages) did a similar task, they used only one of the two (metrical or syllable) strategies which might have been available to them (Cutler et al., 1992). Cutler claims that the strategy used corresponds to that used by native speakers of the subject's dominant language. This interpretation, however, has been called into question. Language dominance was determined after the experiment in an unorthodox manner. Subjects were asked to choose which of their languages they would prefer not to loose after an accident; the elected surviving language was considered to be dominant. The *post hoc* and unorthodox manner of determining language dominance prompted criticism of the interpretation of this experiment and have diluted the impact of its results.

The claim which emerges from the cross linguistic studies is that the prosodic segmentation strategies emerge from the exposure listeners have to consistent prosodic patterns. Listeners to English are exposed to the metrical alternation of strong and weak syllables. The partitioning of the English lexicon is heavily weighted in favour of strong syllable initial words. In addition, those words beginning with strong syllables tend to be more frequent (Cutler, 1990). A major counter intuition to this claim stems from the fact that a large proportion of most utterances consists of closed-class items which are typically monosyllabic and rarely comprise strong syllables. Cutler, in defence of her position, states that even assuming that all monosyllabic functors are weak syllables, 73.32% of the lexicon[6] and 73.46 of open class items are strong syllable

[6]Percentages are based on a survey of 13,000 most common British English words.

initial (Cutler & Carter, 1987). Conversely closed-class items were only 25% polysyllabic with strong initial syllables. This need not render the strategy inefficient as it is unclear whether functors are accessed is the same fashion as lexical words (Shillcock & Bard; In Press). It would seem, therefore, that the lexicon exhibits a prevalence of one particular type of metrical structure. Work with infants suggests that the sensitivity to such prosodic patterns emerges early in cognitive development (Jusczyk et al., 1993). The extensive exposure that the lexicon provides to words with strong initial syllables and the early hard wiring of this information as reflected in the infant preference for strong syllables, makes the retention of a sensitivity to metrical stress and its use as an aid to lexical segmentation, a viable prediction.

5.5.2. Alternative interpretations of Cutler et al.'s data

Although Cutler et al.'s findings are in general well accepted, there are several other possible interpretations of the data they have collected. Cutler and Norris deal with many of the arguments against the the existence of an MSS in the series of investigations referred to above (Cutler & Norris, 1988). Those most relevant to the present experiment are those advanced by Bard (1990) and Diehl (1985). Bard explains that Cutler and Norris's experimental results can be accounted for without appeal to a separate mechanism like the MSS. Invoking Occam's razor, Bard asserts that a processing architecture without the MSS is more desirable. TRACE and an appreciation of English phonetics predict that weak syllables, being relatively unintelligible compared to strong syllables, would engender more numerous but less activated hypotheses for recognition. Strong syllables give rise to cohorts containing less numerous yet highly activated competitors. Bard proposes that monitoring for *mint* in *mintayve* is delayed because the set which competes to be matched with *tayve* consists of highly activated candidates which remain highly active, possibly until after the offest of the second syllable. Until the array of competitors decays below the level of *tayve*, *mint* cannot be recognised. The cohort activated by the weak syllable *tef* is not so highly active and will take less time to decay, to a level where *mint* can be recognised.

Further objections concern the effect of the vowel quality and length and how these effect overall length of token which in turn delay reaction time[7]. It has been claimed, as

[7]Culter & Norris (1988) deal with this issue.

predicted by Diehl et al.'s finding (1985), that the vowel length of the adjunct (e.g. -ayve) masks the identity of the target word; that is, the delay is due to masking rather than need for reanalysis. Alternatively, the delay may simply reflect the length of time the listener has to wait till the end of the token before a decision is made; strong syllables will typically be longer than weak syllables and will form longer words which, if the length delay hypothesis were correct, would in turn elicit the longer reaction times as a function of the overall word length. If the delay is a result of length and intensity of the second syllable then differential reaction times will be found in words that would not require reanalysis (those for which the triggering of a second lexical access attempt would not split the target word such as **thin** tayve) as well as those that do such as **min** tayve. A comparison of response speed to these two types of items (Cutler & Norris, 1988) showed that it was only the **MINT-TYPE** words, which were capable of being split by the proposed segmentation, that show faster response speeds for the target in weak syllable environments. The second set of **THIN-TYPE** materials were recognised with equal latency in both weak and strong contexts; i.e. "thin" was recognised equally quickly in **thin***tayve* as in **thin***tef*. It can be inferred then that the initial data did reflect a more complex process than could be accounted for by invoking arguments of syllable-intensity, masking or delay due to total word length.

5.6. Aim of current investigation

The current chapter has two aims related to these results. The first is to assess the use of metrical prosody in segmentation by fluent aphasics. The second is to make a statement on the status of the mechanism in the undamaged processor in the light of the pathological performance. The hypothesis for the fluent aphasic subjects is that, because of their generally unimpaired prosodic processing, they will retain the use of metrical stress as an aid to perceptual segmentation.

5.7. Word Spotting Paradigm

To test this claim one can create environments which cause erroneous segmentation. The present design is an off-line replication of that used by Cutler & Norris (1988). A nonsense word like *stampoaj* contains two strong syllables and should elicit two access attempts, leading to segmentation as *stam poaj*. To parse the string as *stamp oaj* (and thereby recognise *stamp*) this initial erroneous boundary would have to be bridged. No such bridging would be necessary if the string contained a weak second syllable "*stampej*" as only one lexical access trigger would be activated. I hypothesise that target words followed by weak second syllables would be more rapidly and accurately recognised.

Cutler & Norris' work investigated real-time detection latency of words embedded in nonsense strings (e.g. finding *mint* in **mint***ayve*). The current extension of the paradigm demands off-line responses from subjects whose on-line responses may be uninterpretable. With impaired subjects, the chances of getting a 'floor' effect with a timed word spotting paradigm are high. Tasks of this complexity often elicit R.T.s of the order of 1000s of ms, and at that R.T. magnitude one cannot make a principled claim that the reaction time variation reflect on-line processing difference. The demands of the task are such that difficulty of processing will be reflected in absolute response rather than position on a continuum; words in 'difficult' contexts will **not** be spotted at all, while words in 'easy' contexts will be spotted (absolute), rather than 'difficult' words being spotted more slowly than 'easy' ones (continuum). A non-timed variant of the response method is, therefore, more meaningful. In normal subjects it was hypothesised that the presence of the second strong syllable in items such as **mint***ayve* hindered detection to such an extent that word detection was delayed relative to the detection of the same word in a weak syllable context (e.g. **mint***ef*). This delay translated into longer reaction times by normal listeners. The current hypothesis states that, in the case of MINTAYVE-TYPE words the effect of the metrical segmentation mechanism for impaired listeners will manifest itself as non-detection.

In other words, the MSS will result in a second segmentation attempt in the strong syllable condition, this will increase the difficulty of processing (because bridging will be required for successful word recognition) and in some cases the level of difficulty will be one from which the aphasic listener cannot recover and word recognition will not be successful. For normal subjects, longer reaction times are elicited in strong syllables because of the need to re-segment the MIN-TAYVE stimuli. Aphasics will fail to find *mint* in such contexts as they <u>do not</u> re-segment.

If this effect can be replicated with aphasics, then a clearer picture of the surviving perceptual abilities of aphasics will emerge. In addition, such a demonstration would support the original claims of Culter et al. It has been suggested that the results of the original work were artifacts of the on-line nature of the paradigm. If similar results are found in damaged processors, using an off-line measure, the case for the existence of a specific strategy would be strengthened.

5.8. METHOD

5.8.1. Requirements of the hypothesis

The study demands a means of attributing successful lexical access to the appropriate employment of metrical prosody. Clearly the method chosen requires that lexical level biasing of lexical access choice must be constrained. The paradigm chosen for use here is an adaptation of that pioneered by Cutler and Norris (1988). Our hypothesis is tested by constructing an environment in which strong syllables, if they do trigger segmentation attempts, would cause inappropriate segmentations in that they would hinder detection of the word embedded within the nonsense environment.

5.8.2. Variant of paradigm used in the present investigation

The hypothesis explored in the original paper (Cutler & Norris, 1988) was that the inappropriate segmentation attempts caused by the strong syllables, would delay detection of the target words in these environments. The aphasic subjects used in the current experiment were not suited to reaction time methodology. They suffered from a physical slowness and lability which would have produced unacceptably large reaction-time variance. An off-line variant of the task was used, which demanded yes/no responses to materials which did or did not contain an embedded word. The ceiling effect which such a task would produce in normal subjects is not expected with aphasics.

5.8.3. Design

A repeated measures with crossed subjects design was used. The materials had the following design: Context type (2 levels; weak second syllable, strong second syllable) x (for a subset of materials) Word type (2 levels; Cluster final {MINT-TYPE}, Single consonant final {THIN-TYPE}). All subjects heard all tokens in all conditions.

The off-line word spotting experiment explores the hypothesis that prosody is implicated in word segmentation. Specifically, it investigates the theory that strong syllables trigger lexical access attempts, thereby facilitating parsimonious segmentation of the speech stream. The null hypothesis is that there will be no significant difference between detection rate for initial syllable words when the second syllable is strong and when it is weak.

5.8.4. Materials

The tokens were adapted from Cutler and Norris's (1988) study. In the original investigation words were selected in pairs of rhyming items (*mint, hint; act, fact*). Many of the rhyming partners were not imageable enough to be accommodated to a response paradigm which required pictorial images. The targets therefore comprised twenty-two monosyllabic **MINT-TYPE** words which contain short vowels and consonant cluster offsets, eg *mint, jump*. No other words could be formed by removing the final consonant (i.e. *jum* is not a word). The experimental materials were formed by appending to each target two alternative endings: either of a full vowel and consonant (eg *ov*) or a schwa plus consonant (eg *əv*). In the resulting pairs of nonsense bi-syllables (eg *mintayve* and *mintef*) each monosyllable is found in both a strong syllable environment **(SS)** and a weak syllable environment **(SW)**.

A set of foils which rhymed with the target items was included. For instance, materials such as *gumpoaj*, which contrasts with the experimental material *jumpoaj* were included. The target word in the foil item is a **THIN-TYPE** word containing a short vowel and a single consonant offset. Thus, the word final segment in each contains the same phonetic material but only one target word straddles the syllable boundary. A full list of materials can be found in Appendix B. The auditory materials were all recorded by a female speaker of Scottish English.

The second tier of the response involved matching target words to graphic representations. All target words and foils had a corresponding graphic representations. The graphics were mounted on picture boards. Each picture board contained a representation of the target item and two phonologically related distractors. All graphics were of uniform size and the position of target graphic was assigned randomly. They were all prepared using Scanjet Plus on an Apple Macintosh P.C and Image Scanner.

It should be noted that early critics of the original study suggested that if any differential rates for strong and weak syllable contexts were found, such materials would not unambiguously show whether this was due to the presence of a strong syllable segmentation strategy or the different amount of coarticulatory influence exerted by the second syllables. It was argued that target words embedded in strong syllables are less canonical exemplars than those in weak syllables contexts. If this were true, one would predict a difference in detection rates in strong and weak syllable contexts, not because of the functioning of a segmentation strategy but because of the longer processing time needed to recognise less regular exemplars. Cutler claimed that even if there were a significant effect of this sort, it would not manifest itself in longer detection rates. To demonstrate the validity of her claim Cutler excised the targets recorded with both weak and strong second syllables. She found that when the stripped words were presented, they were equally well detected. This implies that any differences in detection rates obtained was not due to the canonical status of the target words. Consequently, no such excision was felt necessary here.

5.8.5. Procedure

Materials were presented over headphones to subjects individually. An "Off-line Word Spotting" response method was adopted: the first tier required a yes/no response to an adapted lexical decision question. The second, a picture pointing paradigm, required identification of the target which corresponded to one of three graphics on a picture board. Picture matching enabled the use of subjects with additional linguistic, and extra-linguistic deficits without risk of these features confounding the results.

Before the test proper, each subject was given a practice session as long as was necessary to satisfy the investigator that they were able to complete the task. The same set induction procedure as detailed for Experiment 1 (Chapter 4, Pg 65.) was employed for this experiment. No subjects were discarded for not being able to complete the task. This was not surprising as the tasks in the first and the current experiment were of equal complexity and the subjects who took part in Experiment 2 were largely the same as those who had done Experiment 1 for which pre-screening had eliminated unsuitable candidates. Practice items, which resembled the test tokens, were played and the answers were given. Analogous printed examples, appropriate to the subject's abilities, were presented to reinforce the task's objective. These included an example using the subject's name enclosed in a nonsense format *e.g. BERTel* or *BERTain*.

Subjects listened to the taped bi-syllabic nonsense items and were asked to indicate whether they recognised any real words contained within. If they responded positively they were to indicate whether it matched any picture on the board and/or utter the word. Both tiers of response had to be correctly completed for a correct response to be recorded.

5.8.6. Subjects

Ten fluent aphasics took part. All were assessed on WAB (Kertesz, 1979) or BDAE (Goodglass and Kaplan, 1972) and on auditory and visual perception areas of the PALPA (Kay et al., 1988) and related batteries (Franklin, 1989). All were classified as having auditory perception deficits and impaired lexical access. Full profiles for each subject are contained in Tables 5-2, 5-3, 5-4.

5.9. Results

A by-subjects *t-test* revealed a difference in identification of targets as a function of the token's second syllable strength, such that weak second syllables yielded better identification rates than strong; correct word spotting in strong syllables = 46%, in weak syllables= 53%; $t = 2.41$ *(d.f.)* =9, $p < 0.05$: Aphasics found it easier to identify words embedded in nonsense bi-syllables when the second syllable was weak. (See Figure 5-1.) A by-materials analysis yielded comparable result ($t = 2.80$, *(d.f.)* = 18, $p < 0.01$) The targets with weak second syllables were more successfully identified than those with strong second syllables. There was no significant difference in the detection of words with single final-consonants (THIN-TYPE words) followed by strong or weak syllables ($t = -0.31$, *d.f.* = 5, $p <1$).

A subset of the consonant cluster words (MINT-TYPE) had matching single consonant final foils (THIN-TYPE). An Analysis of Variance was conducted on these materials to

Table 5-1: Experiment 2: Aphasic Subject Profiles

Subject profiles						
Patient	***Sex***	***Age***	***Time Post Onset (months)***	***Aetiology***	***Occupation***	***Aphasia Type***
F I	M	72	10	Left CVA	Engineer	Fluent
E K	M	48	10	Left CVA	Builder	Fluent
J A	M	39	13	Head Injury	Barman	Anomic
J D	M	40	10	Head Injury	Electrician	Fluent
A L	M	62	12	Left CVA	Manager	Fluent
M S	F	60	12	Left CVA	Housewife	Fluent
E T	F	52	19	Left CVA	Housewife	Non-Fluent[8]
S W	F	29	09	Left CVA	Air Steward	Fluent
M B	M	70	14	Left CVA	Laborour	Fluent
B H	M	66	12	Left CVA	Engineer	Fluent

Table 5-2: Experiment 2: Aphasic Linguistic Profiles

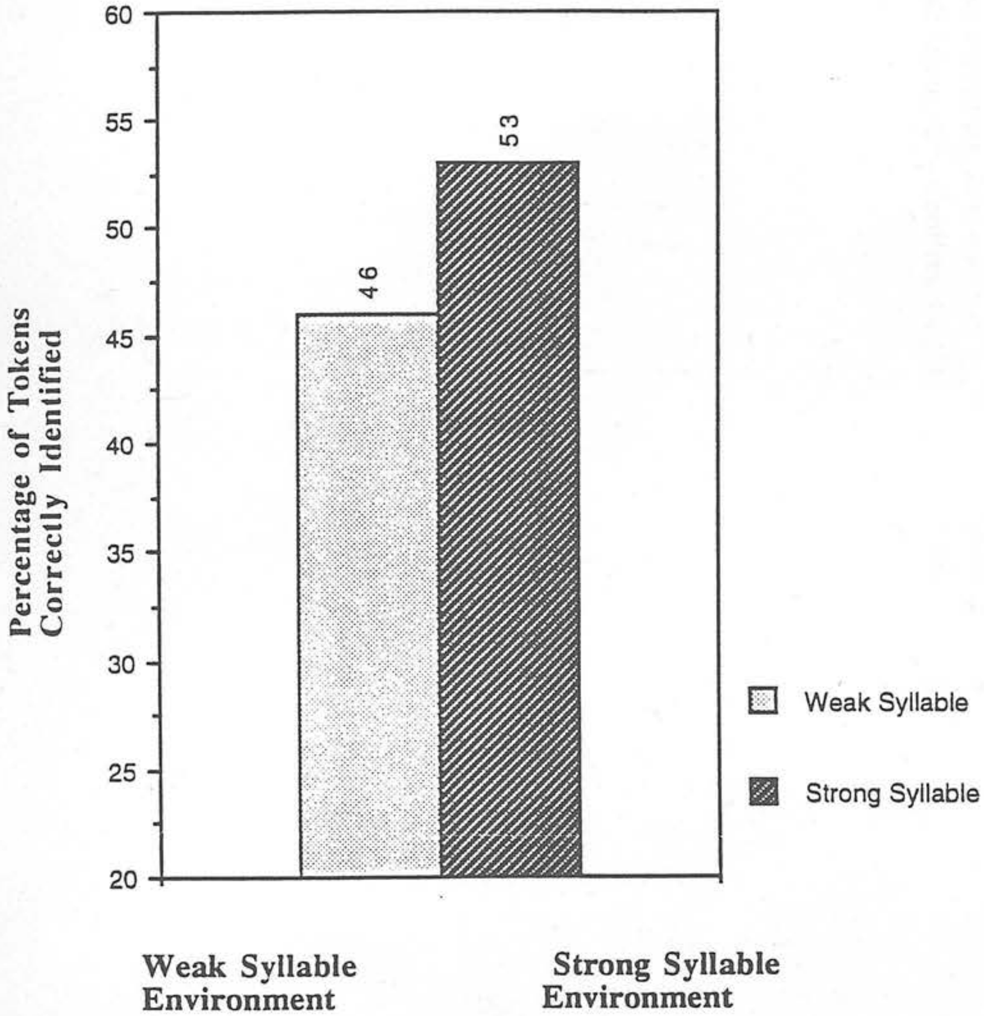
Aphasic Subject Linguistic Profiles						
Name	***CVC Aud. Discrim.***	***CVC Non-word Discrim.***	***Aud. Lexical Decis.***	***Visual Lexical Decis.***	***Word-Picture***	***Aud. synonym matching***
F I	.84	N/T	.80	N/T	.66	N/T
E K	.94	N/T	.91	N/T	.78	N/T
E T	N/T	N/T	N/T	N/T	N/T	N/T
J A	1	1	.93	N/T	1	.92
J D	.81	.81	.85	N/T	.93	N/T
A L	.90	.85	.91	.91	.83	.94
B H	N/T	.60	N/T	N/T	N/T	N/T

[8]See Table 4.2

Table 5-3: Experiment 2: Aphasic subjects Linguistic Assessments

Aphasic Subject Linguistic Profiles - Summaries of Linguistic Assessments.	
Name	***Summary of linguistic skills***
M S	Low scores on "Palm tree and Pyramids" test, and lexical decision tasks. Exhibits perseveration. Previously had severe naming difficulties, now only mild.
E T	Residual comprehension disorder with predominant expressive problems. Telegraphic non-fluent speech style. Auditory perception impaired.
S W	Word finding and naming deficits. Comprehension levels recovering, auditory perception still impaired.
M B	Severe expressive and low-level perceptive difficulties. Functional comprehension very poor.

Figure 5-1: Percentage of target words correctly identified: Strong versus Weak Environments.



	Weak		Strong	
Possible Total	15		15	
Mean	8.6	(53%)	41	(46%)
Range	10		5	
St. D.	2.7		2.5	
Min	4	(29%)	5	(33%)
Max	14	(93%)	13	(87%)

examine the interaction of syllable strength (weak versus strong) and syllable structure (single consonant versus consonant cluster). This ANOVA, however, yielded no significant main effects of interactions. The effect of syllable strength was not significant (F_1 = 0.69 (1,9) p > .1, F_2(1, 7) = 2.57 p >.1), nor was the effect of syllable type (F_1 = 2.78 (1,9) p >.1, F_2(1, 7) = 1.20 p > .1) and nor was the interaction between the two (F_1 = 0.15 (1,9) p >.4, F_2(1, 7) = 0.85 p > 0.1). The failure to find any effects here may be largely due to the small data set employed.

The main findings (as displayed in the *t-test* results) echo those of Cutler & Norris (1988). On the one hand word spotting reaction times in consonant cluster final words (MINT-TYPE) were significantly faster in weak syllable contexts than in strong syllable contexts but on the other hand, single final-consonant (THIN-TYPE) words promoted no differential reaction times as a function of syllable strength.

The present results differ from those of Cutler and Norris (1988) in one important respect. In the current study the detection of the single final-consonant words (**THIN-TYPE** words) was low in both strong and weak syllables, and on a par with the detection of cluster-final items (**MINT-TYPE** words) in the "difficult" strong syllable condition. In Cutler & Norris's study, the single final-consonant words were detected as well as the consonant cluster items in the "good", weak syllable condition. One reason why this discrepancy may have arisen lies in the lexical characteristics of the **THIN-TYPE** words.

5.9.1. Correlations between lexical features and spotting of the foils

It is possible that the single final consonant words (**THIN-TYPE**) were less accessible to subjects with damaged processing. In order to explore this hypothesis lexical characteristics of the experimental and foil materials were examined. All materials had been screened to accommodate the potentially limited access to rare vocabulary on the part of the aphasic subjects but it was not possible to avoid the inclusion of some more obscure lexical items. All items were therefore examined from the point of view of four measures of lexical obscurity: frequency, familiarity, concreteness and imageability[9].

[9]Frequency ratings were obtained from the Francis and Kucera frequency analysis (Francis & Kucera, 1982) while all other lexical ratings were taken from the MRC Psycholinguistic Database (Coltheart, 1981).

Correlations were then computed to investigate the effect of these four variables on the scores for the single-consonant items. There were no direct correlations between any of the measured lexical features and overall detection rates for filler items. Table 5-4 shows the resultant non-significant correlations.

Table 5-4: Correlations across Lexical Features and Word Detection

Correlations of Lexical Features with Word Detection				
Word Type	***Imageability***	***Concreteness***	***Familiarity***	***Frequency***
THIN-WORDS	r = 0.31	r = 0.066	r = 0.005	r = 0.114
	P>1	P>1	P>1	P>1
MINT-WORDS	r = 0.07	r = 0.021	r = 0.145	r = 0.374
	P>1	P>1	P>1	P>1

Frequency and imageability were most strongly positively (yet not significantly) correlated with detection rates of **THIN-TYPE** words. A correlation between word frequency and word type (i.e. **THIN-TYPE** or **MINT-TYPE** word) showed that **THIN-TYPE** words were less frequent. Despite there being no significant correlation between correct identification of individual words in the consonant final conditions, there was a significant relationship between frequency values and membership of the cluster final/consonant-final word class: the single final-consonant words were less frequent. Fluent aphasics are reliably sensitive to word frequency; the frequency bias in the present materials may have been sufficient to reduce the detectability of the consonant final cell and thus bring down success rates for all consonant final items to the level of the hindered (SS environment) cluster final targets. Detection levels were therefore no longer analogous to those of the weak syllable environment items reported by Cutler et al. with normal subjects.

A similar set of analyses were undertaken to test any effects that the lexical characteristics of the words may have exerted on word detection in the cluster-final (**MINT-TYPE**) items. Note that any correlations between word features and correct identification can only have implications for overall detection levels and not for comparative detection across syllable strength conditions. Very high correlations between word features (e.g. frequency, familiarity, concreteness, and imageability) and correct identification, might indicate that the pattern of detections across contexts was being masked by an overall inability to detect the target words *per se*. In short, the listeners may not be able to access the words in whichever prosodic context because the words are excessively obscure rather than because their access is hindered by prosodic environment. See Table 5-4 for correlations.

As was the case with the **THIN-TYPE** words, none of the tested correlations were significant. As before, all were in the predicted direction with the trend being largest for frequency. The non-significant correlations indicate, however, that no particular word feature was likely to have a significant effect of reducing the detection of target words to an extent that would mask or exaggerate the differential detection of each target word in the two syllabic conditions.

5.9.2. Individual Subjects

Individual subjects all followed a similar pattern of behaviour. A residual score analysis showed a homogeneity within the group's performance sufficient to claim the group behaved as a single population. One subject (A3) detected one more word in the strong syllable environment than in the weak, but this was not sufficiently against the general bias to warrant particular investigation. No significant correlations emerged between performance on this task and scores on the profiling tests. The retention of this strategy bears no particular relationship to level of ability in auditory discrimination, lexical decision or word identification.

In brief, the aphasics were significantly better at spotting target words when they preceded a weak syllable than when they preceded a strong syllable. The inherent properties of the following syllable strength are not in themselves predictive of the aphasic word spotting -- consonant final words are not spotted differently as a function of following syllable strength. Rather, syllable strength is relevant because it promotes segmentation: strong second syllables erroneously promote segmentation of cluster final words and therefore hinder spotting of preceding words.

5.10. Discussion

5.10.1. Theories of segmentation

The present findings qualitatively replicate the principal finding of Cutler and Norris (1988): strong syllables appear to promote segmentation which can inhibit the recognition of words spanning such boundaries and which would necessitate recompilation of the word over the boundary. The strategy available to normal listeners seems to be sufficiently robust to survive into the post-morbid state: the post-pathological processor is not reorganised with respect to its utilisation of metrical prosody. Although the aphasics' word spotting ability is quantitatively impaired compared to that found for normals by Cutler and Norris (1988)[10], both normal and aphasic listeners show differential word spotting performances in strong and weak second syllable contexts. This qualitative replication of normal behaviour has ramifications for our views of the structure of the normal, unimpaired language processor. It strongly suggests that the MSS is embedded at a fundamental level making it resistant to damage. Evidence to support this view can be found in data from infant language processing literature. Jusczyk et al., (1992) reported that 9 month old American infants listen longer to words with Strong/Weak stress patterns than they do to words with Weak/Strong stress patterns. It is proposed that this increased attention reflects the infants' "increasing familiarity with the predominant stress pattern of English" (pp 20). This difference in attention holds when the materials are low-pass filtered. Jusczyk et al. suggest that this is evidence for early sensitivity to prosodic structure and that it is an important stage in the development of segmentation for lexical access (Jusczyk et al., 1993). These results suggest that sensitivity to metrical prosody is apparent at very early stages of the development of the lexicon and has an important role to play in the extraction of words from continuous speech at at early age. As such, they imply that metrical prosodic information would be incorporated at a fundamental level of processing.

Failure, in the current study, of subjects to identify all words (even in weak syllable

[10]Cutler & Norris (1988) report a 96% recognition rate for all words; for normal subjects, latency, rather than accuracy, is affected by syllable strength. The aphasic subjects in this experiment had a mean of 53% success in weak syllable contexts and 46% in strong syllable contexts.

environments) is to some degree attributable to non-prosodic processing impairments. The present results do not allow us unequivocally to ascribe their provenance to either specific phonological perception impairments or a generalised attenuation of processing ability. The fact that the errors are distributed across all subjects and arise from materials of all phonological types suggests, however, that a general degradation of processing is the more credible hypothesis.

The fact that there are more cases of failure to identify words in the strong syllable context than in the weak syllable context bears out the prediction that, in addition to the non-prosodic impairments, the strong syllable context presents a further hindrance to word-recognition by acting as a misleading lexical access trigger. Unlike normal subjects, the aphasic fails to recover from this error.

The present results show that detection was inhibited when the cluster final item was presented in a strong syllable environment and when consonant final items were presented in both strong and weak syllable contexts. This pattern of results strengthens our claim that the results are due to the working of a strong syllable segmentation strategy rather than simply the length or weight of the second syllable masking the identity of the target item. Furthermore, the fact that our data were collected using an off-line methodology, adds weight to Cutler's defence of the original results against criticism that the findings were an artifact of the on-line paradigm used.

5.10.2. Pathological processing

5.10.2.1. Nature of the pathology

The Metrical Segmentation Strategy seems to operates post-morbidly. Fluent aphasics, at least, show sensitivity to metrical stress in word recognition. Sensitivity to and functioning of metrical stress in (LBD) patients parallels Blumstein's findings regarding the retention of lexical stress processing. Emmorey's (1987) results are at variance here. It is not clear though, the extent to which one can draw inferences about metrical stress processing from knowledge of lexical stress processing. This limits the usefulness of direct comparisons with either of these studies. What is clear is that metrical stress is the prosodic level of information useful for segmentation.

5.10.2.2. Implications for therapy

Effective development of rehabilitation practices entails improving the efficiency of capacities which the patient has retained in order to enhance overall communication. If the MSS is retained, it could be exploited in this way to enhance comprehension capacities of impaired listeners. Kimelman's (1991) analysis of the use of emphatic stress in remediations similar to those which one might try with fluent-aphasics were largely pessimistic; both speech rate reduction and increased emphasis are only beneficial to some of the people some of the time.

As Butterfield and Cutler's work showed, manipulation of metrical stress can be used to enhance word recognition without the listener's explicit awareness. This augurs well for the use of this prosodic feature in therapy; its use would not be prone to many of the drawbacks that other prosody based therapies have encountered. Melodic Intonation Therapy (Sparks & Holland, 1976) for example, has limited use because of its demands for metalinguistic reflection, which presents a particular drawback for some fluent aphasics who are poor at self monitoring and using metalinguistic awareness. Whether a prosodically based or connectionist interpretation is given to the current results it would appear that aphasic word recognition and boundary alignment could be improved more effectively by compensating for the least perceptible (in the terms of the MSS) or the most problematic (in the terms of connectionist/TRACE architectures) elements (weak syllables) and by taking the behaviour of non-pathological listeners in difficult listening conditions as a model.

5.10.3. Reinterpreting the Metrical Segmentation Strategy computationally

For the sake of parsimony, architectures are more desirable if they do not have to incorporate a specific uni-functional device for word boundary detection (Bard, 1990). For this reason it is worth considering alternative interpretations of the results obtained in the current study. Computational analysis and connectionist architectures provide an opportunity to do so. Computation of transitional probabilities between segments (phonemes) offers a non-prosodic explanation for the weak syllable advantage for word monitoring found in the current data. Consideration of the lexicon reveals that biphones (pairs of adjacent phonemes) occur with differing frequency; some are more commonly found than others. This feature of the lexicon is fundamentally instantiated in connectionist architectures. The transitional probability of one phoneme occurring after another affects the stability of the representation activated when those two elements are perceived together. For instance, when a /t/ is perceived, and the following element is perceived as a /ə/, the chances are high that this is a worthwhile hypothesis for the processor to pursue -- many words contain the biphone /tə/. The representation established for this hypothesis will be fairly stable. Feedback to the /t/ element will be positive, reinforcing the prediction by the processor that /t/ is in fact correct (rather than /k/ or /d/ or /p/ etc.). If, on the other hand, the element after /t/ is perceived as /ei/, the chances that the processor has this right are slimmer -- the lexicon has fewer examples of this biphone occurring. The representation established for the biphone /tei/ will be less well-supported by the lexicon than the one for /tə/. As the /t/ has not been as well established, the representation for *mint* is potentially not as stable a hypothesis as other contenders and will take longer to identify.

There is, however, a problematic aspect to such an account. In general, word recognition benefits from the production of stable representations, except when those representations are erroneous. Such would be the case when the input consisted of /t/ at the end of a word and /ə/ belonging to a new word (or in the case of our experimental materials -- a nonsense ending). If the processor builds up a stable representation of a string ending in /tə/ then the disengagement of the /ə/, in order to leave the intended string, will be more effortful than if the representation had been less stable. Therefore, *mint* in *mintef* would be more difficult to extract than *mint* in *mintayve*. This would present an alternative prediction for the experimental materials, though not necessarily for segmentation in general. Results from neural net simulations as well as the behavioural data reported here and by Cutler et al., show that such a prediction is not borne out. Although neural nets (and by analogy, human processors) make forward predictions, the most salient material for the decision process is that which is already being considered (already perceived); thus forward speculation as to the likelihood of continuation would not play such a crucial role. It is more apt to conceptualise the processor such that an element such as schwa would receive lots of top-down confirmation from all of the activated words which contain it. Biphones such as /tə/ will receive confirmation from words like *terrain* which will further support the hypothesis that the /t/ is present.

In neural net simulations of word recognition, calculations of multiple n-grams have simultaneous impact on the representation stability. Here, for simplicity, I will only consider the effect of the biphone and triphone statistics of the experimental materials on representation stability and its consequent effect on a processor's prediction of word boundary.

Inspection of a corpus based lexicon[11] provided representative figures for the relative n-gram statistics predicted from the theoretical consideration of the lexicon.

An examination of the juncture biphones (e.g. /tə/) from the current materials shows that those from the weak syllable contexts *e.g.* *mintef* are significantly more frequent than those from strong syllable contexts (t = 3.57, *d.f.*, 13 P = 0.005.). The difference between the frequency of occurrence of triphones in strong and weak syllable contexts is also significant (t = 2.77, *df*, 13, P = 0.01.). Recall that the materials selected for this experiment were a subset of those used by Cutler and Norris. To confirm that the low-level statistical advantage for the *mintef-type* materials holds for the whole set of materials, further *t-tests* were performed: biphones containing schwa were significantly more common than those containing full vowels, (t = 5.84, df = 17, P = 0.0001.) and triphones containing schwa were significantly more common than those containing full vowels (t = 3.33, df = 25 P = 0.003.).

Next I considered the relative distribution of the schwa versus full vowel (or diphthong) biphones and triphones in different frequency bands of the lexicon. The lexicon was partitioned according to frequency of occurrence of each lexical item. Each item was then assigned membership of one of 7 frequency bands. Distribution of the boundary biphones and triphones was then calculated for words in each frequency band.

Table 5-5 shows the occurrence of the boundary biphones from the experimental materials as a function of the syllable strength (Weak versus Strong) in words from different frequency bands. Biphones of which one member is /ə/ are consistently significantly more common in all but the most frequently occurring words. The triphone

[11]Biphone and triphone statistics were extracted from a phonetically transcribed, on-line version of the London-Lund Corpus (1980) by Joe Levy, Department of Cognitive Science, University of Edinburgh. Where frequency constrained subsets of words were required, an on-line version of the Francis and Kucera (1982) frequency analysis was used to calculate n-gram statistics.

Table 5-5: Biphone Occurrence: Comparative number of words containing Weak and Strong vowel biphones: Units are number of words containing given biphones

FREQUENCY BAND	***SYLLABLE TYPE***	***MEAN***	***SD***	***Difference between Strong and Weak (F)***	***Significance level (P)***
1 - 30	STRONG	167	136		
	WEAK	1515	799		
				52	0.0000
31 - 50	STRONG	2.3	2.8		
	WEAK	22.6	8.9		
				72.74	0.0000
51 - 100	STRONG	1.5	1.8		
	WEAK	15.6	6.1		
				78.6	0.0000
101 - 200	STRONG	0.94	1.0		
	WEAK	6.8	1.3		
				109.4	0.0000
201 - 300	STRONG	0.3	0.6		
	WEAK	1.4	1.5		
				5.43	0.299
301 - 400	STRONG	0.05	0.2		
	WEAK	0.8	0.8		
				12.16	0.0022
401 - 500	STRONG	0.2	0.5		
	WEAK	0.2	0.4		
				0.02	0.8968

statistics show the same pattern of 'schwa triphone' advantage[12]. The lack of difference between occurrence of '/ə/ biphones' and 'full vowel biphones' in high frequency words can largely be accounted for by the nature of the frequency analysis tool used; the text

[12]The patterns are so similar that they are not recorded here.

based Frequency analysis of English Usage (Francis & Kucera, 1982). Many of the highest frequency words in English are monosyllabic, and in the citation form which is recorded in the frequency analysis used they contain full vowels. In natural speech, many of these, especially closed-class words, typically reduce to schwa. It is possible, therefore to conclude that at a statistical level, the structure of the English lexicon would predict that the presence of a weak syllable would produce a more secure biphone and not favour segmentation at this point.

5.10.3.1. Interpreting Aphasic Data

The computational account provides a clearer account of the aphasic results. The computational explanation accommodates both the results of the aphasic performance on the experimental materials and the foils. A distributed representation architecture would assume an account of aphasic processing centered on the notion of graceful degradation. Destruction of several units or connections between them, rather than totally destroying a particular capacity, leads to a general lowering of processing strength. In the case of the MINT-TYPE items, in the weak syllable condition, the goodness of the representation would be derived from two main sources; reinforcement for the *mint* hypothesis will come from the lexical level as it is a relatively frequent word, secondly the presence of the /ə/ after the /t/, will reinforce the local hypothesis that /t/ is being perceived. Reinforcement does not appear to have as powerful effect as for normal listeners, as some words even in this most favoured cell are not identified. In the strong syllable environment, the lexical reinforcement is as strong but the sub-lexical transitional probability of the /tei/ string does not provide such strong confirmation of the /t/ so in many cases *mint*-type words do not reach a level of stability at which recognition is possible.

With many **THIN-TYPE** words, neither the strong or weak syllable environments provide sufficient stabilisation from the trigram level /ntə/ or /ntei/ to overcome the lack of lexical effect. Therefore the level of identification is generally low.

This fits well with the updated version of the MSS (Norris et al., 993a, Mcqueen et al., 1993) in which the MSS assumes the status of a lexical level effect rather than that of a purely extra-lexical strategy. It is thought to give a boost to lexical access rather than drive the initiation of access attempts. Norris et al. propose that the MSS interacts with competition effects in the lexicon and shows an effect when the target has many competitors. That is, the MSS and competition effects provide a combined penalty on the recognition of words like *mint* in strong syllable contexts when the /t + vowel/ is the beginning of a large cohort of competitors. Clearly on this interpretation the aphasic subjects are being inhibited by competitor effects (here, frequency rather than number of competitors) but are further hindered by the MSS penalty.

5.11. Summary Conclusions

Fluent aphasics appear to retain sensitivity to metrical stress in that their ability to spot words in nonsense contexts appears to be disturbed by the presence of strong syllables which cause them to initiate erroneous lexical access attempts. When in weak syllable contexts, word spotting is more easily accomplished but even this is below normal levels of accuracy. The current data can be accounted for most fully by invoking a computational account of the processing of full versus reduced vowel/schwa syllables. The transitional probabilities of the boundary segments used in the current materials are highly skewed as a function of metrical class: the transitional probabilities at the strong syllable boundaries are much lower. I propose that the transitional probabilities between phonemes play an important role in the development of the goodness of lexical representations in normal processing and that aphasic subjects continue to accrue a processing advantage from this goodness of representation.

The biphone data can be viewed, at least in part, as a lexical statistic which explains why the metrical pattern of language has an impact on lexical access. I propose that the present results reflect a genuine retention in fluent aphasia of sensitivity to the statistical probability of phoneme co-occurrence. In the materials used for the current experiment, this necessarily led to the facilitation of detecting the targets in the weak syllable context. I posit that, in the course of more natural processing, this sensitivity provides additional facilitation for, but does not rule out the inclusion of, the use of prosodic cues to segmentation in fluent aphasia.

Chapter 6

Segmenting Carrier Words to Expose Embedded Targets.

6.1. Introduction

In this and the following two chapters, I will discuss the problems for segmentation presented by overlapping lexical hypotheses. Acoustic strings regularly present multiple parsing possibilities. A sequence such as *cat* could be aligned with the beginning of a word hypothesis and the word *CAT* would be activated. Equally, it could be the start of the word *CATtle*. Alternatively the string could correspond to the middle section of *conCATenate* or the end of *poleCAT*. An integral part of speech recognition is the task of determining which of the overlapping word hypotheses is the one intended by the speaker. In this chapter I focus on the processing of strings which offer overlapping hypotheses like *trom***bone**; that is, polysyllabic hypotheses whose final portion also corresponds to an independent monosyllabic hypothesis (**bone**). The recognition of such strings as the intended polysyllable, crucially relies on resolving the competition between the monosyllable and polysyllable parsings.

In ideal listening and speaking conditions we might assume that prior context would be sufficiently explicit to specify a single candidate by the time of the word offset. Luce's (1986) observation that 60% of words do not have a uniqueness point before their offset suggests that this is not always feasible. Features of realistic listening conditions also conspire to make the use of this type of top-down lexical information less reliable than might first be expected. First, we listen to much speech in the context of background noise. This degrades the acoustic information on which listeners must base their hypothesis of what is being spoken. Often acoustic detail of the utterance is underspecified and the identity of an intended phoneme or lexeme is indeterminate at the phonological level. Spontaneous speech is also typically disfluent in that it is littered with hesitations, repetitions and self-corrections. This renders the use of grammatical predictors unreliable. Further, running speech is generally received at enormous rates and in enormous quantities making speed of processing a fundamental requirement of successful recognition. So, however, is accuracy. Given the paucity of the signal and the time constraints imposed by the need to comprehend as quickly as possible, how is recognition accomplished?

Some of the most well accepted accounts of how the speed/accuracy trade off is resolved are those presented by the activation models such as the revised Cohort Model and TRACE. Both theories assert a multiple activation mechanism which states that until a felicitous parse is found for the input string, recognition of an individual word involves multiple contending hypotheses. Any mechanism of this sort must present the listener with multiple erroneous competitors along with the intended word. In general, however, listeners understand speech. This implies that they have resolved the ambiguities created by the overlapping lexical competitors: one lexical hypothesis dominates all others. In many cases, for successful recognition to occur, the recogniser has had to activate word hypotheses which, in the speech stream, are embedded at the end of other potential words: to recognise *rain* in <u>its</u> <u>going</u> <u>to</u> <u>rain</u> the word *terrain* may have to be suppressed. This study explores how, and to what extent words which are embedded at the end of longer contenders are activated and how they may be recognised in appropriate circumstances.

6.1.1. Activation of Word Final Hypotheses

Let us first examine the current understanding of final embedded-word activation. While the question of activation of <u>word</u> <u>initial</u> <u>embedded</u> <u>hypotheses</u> has generated wide interest (see Chapters 7 and 8), there has been little exploration of activation or competition concerning <u>word</u> <u>final</u> <u>embedded</u> <u>word</u> in either mainstream psycholinguistic, or the aphasiological literature.

6.1.1.1. Simulation Data

One treatment of the phenomenon of activation of multiple overlapping competitors comes from computational modelling of psycholinguistic processes. The most notable is the series of simulations of the TRACE model conducted by Frauenfelder and Peeters (1990). They tested the predictions for activation of word-final embedded words (henceforth EWs) relative to that of word-initial embedded words and carrier words (henceforth CWs), using computationally generated data on a simulation of TRACE. TRACE purports to emulate the human speech processor and can be used to track and record the activation of competitors during word recognition.

Of the numerous simulations which comprised the Frauenfelder and Peeters study, three pertained to EWs which overlapped at the end of the CW. In the first simulation (No. 4 in Frauenfelder and Peeters' series) the input consisted of CWs (e.g. *precede*) whose word initial segment was not a word, *pre*, but whose final EW corresponded to a word (e.g. *seed*). In such cases the word final EW never became highly activated. By the time the EW word was entertained as a hypothesis, the polysyllable, whose activation had been initiated earlier, had accrued sufficient (non-competed) activation to suppress the emergence of the word-final candidate. A further simulation used CWs containing two EWs; (e.g. *suck* + *seed* in *succeed*). In this test, the simulator interpreted the string as one long word (*succeed*) as opposed to two short items (*suck* + *seed*). Of the two EWs the initial item (*suck*) received the most activation. The final EW, however is less inhibited than when it is preceded by a non-word-initial segment (*pre+seed*). They found that final EWs preceded by initial EWs experience greater activation than those where the initial syllable of the CW is a non-word. They suggest that the word-initial EW exerts more inhibition on the CW thus attenuating the CW's power to inhibit the word final EW; when the initial syllable is a non-word activation of the CW is not damped. When the simulation was repeated with a boundary marker inserted between the two EWs, the CW failed to inhibit either EW, allowing both to reach recognition level.

The competition environments to be examined in the current investigation resemble most closely the words in the first simulation (e.g. *precede*). They are bi-syllables whose first syllable does not correspond to a word but second syllable does. Taken at face value, the TRACE simulations would suggest that the word final hypotheses would not be activated sufficiently to act as competitors for segmentation decisions. It is notable (and acknowledged by the authors), however, that the simulations are highly artificial in that the lexicon used is small and no role is ascribed to competitor set size and frequency of competitors. Subsequent studies (Frauenfelder, 1993) have addressed some of these issues by using a more realistic lexicon, and more constrained competitor set features. He found that manipulating the presence and absence of embedded word competitors had a dramatic effect on the recognition of the target carrier word.

6.1.1.2. Behavioural data

Priming paradigms have been used to investigate activation of word final hypotheses in human listeners. Swinney (1981) and Prather and Swinney (1977) investigated the priming abilities of partially activated words. Prather and Swinney's work examined how far listeners pursue the processing of embedded word hypotheses when they are found within carriers presented in isolation. The investigators presented their subjects with auditory carriers which also offered two monosyllabic parses (*boy* + *cot* in *boycott*). They found that when a visual probe for the word *boy* was presented midway through *boycott*, recognition of *boy* was facilitated. When the probe was presented at the end of the *boycott*, no such aid was afforded. An associate of *cot* was not primed when it was placed at word final position. Their conclusions concurred with those drawn from the TRACE simulations; that the first EW is activated until the CW stimulation reaches a critical point where it suppresses EW activation completely and the word boundary is perceived as being aligned with the CW. Word-final hypotheses do not receive substantial activation if the word-final material could also be used to combine with prior input to make a longer word. Final embedded words do reach recognition levels.

Shillcock (1989) reported results which contrast with these and offers an explanation for the data collected by Swinney and his collaborators. Like Swinney (1981) and Prather and Swinney (1977) Shillcock also used the Cross-Modal priming technique and found that some lexical contexts did generate priming of word-final EWs. He contrasted the priming abilities of the word-final EWs within CWs of differing morphological complexity: the materials used were either monomorphemic (as were all of Swinney's) or were polymorphemic, prefixed words. Shillcock initially proposed that Swinney's failure to find priming by final EWs was a function of the CWs monomorphemic structure and proposed that prefixed words generated more successful primings. This would be compatible with the prefix stripping of lexical storage postulated by Taft (1979). In the same experiment Shillcock also explored the question of whether orthographic match between the carrier and embedded words is a requirement for priming. That is, do the carrier and embedded word have to be homographs (*port* in *report*)to prime each other? Jakimik et al. (1985) had found this to be the case for word initial embedded words; *message* primed words related to *mess* whereas *definite* did not prime words related to *deaf*.

The findings from Shillcock's experiments are at variance with both the effects of morphological complexity and orthographic identity reported above. Shillcock reports that EWs in monomorphemic CWs primed most robustly. Orthographic identity, on the other hand, was not found to constrain activation of embedded words; homographic embedded words (*port* in *report*) and homophonic embedded words (*lie* in *rely*) prime equally.

One possible explanation for the lack of orthographic effect in the priming studies is that the related probes were not always associates of the most frequent meaning of the homograph. Access to homograph meanings in contexts where neither meaning is favoured, is frequency sensitive (Simpson & Krueger, 1991). Although Simpson and Kreuger showed that the nondominant meaning reached a similar activation level to that of the most frequent homophone competitor, it did so only after several hundred milliseconds and seemed to decay quickly. In Shillcock's experiment the bi-syllabic words were presented in contexts but the contexts did not favour any meaning of the embedded word. It may be that in Shillcock's experiment, when the word *report* is heard, if listeners access any embedded word meanings, it may be that only the most frequent of those meanings is accessed. Because the probes used were sometimes associates of the non-dominant meaning of the monosyllable, priming would not occur.

A partial account for the detection of EWs in monomorphemic carriers is supplied by invoking the theory that increased activation of the carrier word hypotheses suppresses the activation (and therefore the priming) of word hypotheses embedded within. Shillcock suggests that the prefixed carrier materials were more highly activated as a function of their frequency. As the prefixed CWs were, on the whole, more frequent they would cause more inhibition of the embedded items and decrease the EWs priming power. This does not, however, provide a very appealing explanation for the spread of results. Shillcock therefore turned to TRACE activation and competition mechanisms for a more compelling account. He concluded that activation of the EW was a function of the number of different second syllable onsets in the members of the word-initial cohort: the prefixed items such as *report* typically belong to cohorts whose contenders have many different second syllables (*report, release, redress, regret* etc) thus no individual second syllable receives a lot of activation. These data support a notion that prefixed words engender activation in the same way that morphologically simple words do. The difference in processing of the two sets of materials is accounted for in terms of low-level features (number of different second syllable onsets) rather than lexical segregation in terms of morphological complexity. In addition Shillcock speculates that there may be a role for the number of onsets of the EWs too (e.g. the /bou/ cohort in trombone).

Elsewhere, the recognition of polymorphemic words is considered differently. Taft (1979) (also, (Jarvella and Meijers, 1983) suggests that prefixed words are stored in a stripped form which would predict a difference in the processing time needed to detect EWs at the end of monomorphemic words and that required for those which correspond to the stem of the polymorphemic word. The rationale for this being that the prefixed word is stored as a bare stem, that is, the embedded word is stored as a whole and thus easily accessed. Subsequent work on the processing of prefixed words would predict a different outcome. Tyler et al. (1988b) report that prefixed words such as *miscount* are in a *mi...* word-initial cohort; they compete with *mystery* rather than *council* as predicted by the prefix stripping account of processing. Such findings predict that (normal) subjects would treat both types of words in a similar way. One further recent account of prefix processing in Dutch (Schriefers et al., 1991), shows results apparently confirming that prefixed words are identified earlier than their corresponding stems. Schriefers et al. conclude that accessing morphologically complex words, such as prefixed words, involves continuous left-to-right processing, but also that the lexicon retains information about the words' morphological structure to aid identification.

Visual processing of morphologically complex words has shown that readers make nonword lexical decisions more slowly when the nonwords consist of, or contain, real-word stems, (*juvenate, dejuvenate*) than they are non-stem nonwords (Taft and Forster., 1975, Taft & Forster, 1976). They suggest that this is because stems, when stripped of their prefixes, are processed differently to other morphemes. It has also been found that words identical to stems of high frequency words (*vent/prevent*) are classified more quickly than words identical to stems in low frequency words (*patch/dispatch*). It was originally suggested that this was because each word had two lexical entries, one for the bound morpheme and one for the free. In the case of *vent* the bound morpheme has the highest frequency (because *prevent* is a frequent word) and thus inhibits the identification of the free version. This would not be true for *patch*.

Justification for Methodology

In the light of these findings we explored the extent to which aphasics with auditory and lexical perception impairments activated competing hypotheses when determining the location of word boundaries. The study makes direct reference to the cross-modal priming study carried out by Shillcock (Shillcock, 1990) in which he compares the priming effects of word-final EWs in monomorphemic and prefixed bi-syllabic CWs. The experimental materials I use match those used by Shillcock but the paradigm for investigating activation differs. By virtue of constraints imposed by the subjects' cognitive, linguistic and physio-emotional status, I employ an off-line task. The subject groups' severity of deficit and range of impairments rule out the use of tasks as cognitively demanding as cross-modal priming. Instead, I examined post-lexical awareness of EWs. By presenting aphasic subjects with bi-syllabic words and evaluating their ability to detect EWs, we are able to examine that EWs state of activation even after the carrier word has won the competition for recognition. This procedure requires metalinguistic reflection on the materials. We do not therefore purport to assess any temporal relation between the activation of competitors, but rather, to examine the effect of morphological context on lexical access.

The broad aims are twofold; first to find out which contexts facilitate lexical access for people with perceptual and comprehension impairments, and second, which contexts exert such competition that no internal word hypotheses reach recognition level. Recall that a high proportion of input received is underspecified or erroneous so in order to recognise speech in real contexts more hypotheses than are eventually successful must be activated to eliminate the risk of missing the correct word parse. If the aphasic listener allows one candidate to inhibit too strongly or not activate potential contenders, then comprehension will be impaired. By determining whether the aphasic subject is aware that a bi-syllabic word has a word embedded within its final syllable, we can judge whether that EW has had any activation. We posit that any EWs not detected, reflect non-activation of that word or super-activation of the CW which effectively would stop any new word hypotheses being favoured at the EW. This non-normal activation of hypotheses leads to misperception of target words.

Predictions

As I have shown, results to date have been less than conclusive as to the relative activation of EWs in differing morphological contexts and differing lexical features. However given the results discussed above we would predict the following for the behaviour of a fluent aphasic subject sample and their non-aphasic controls.

- The control subjects, with an unimpaired capacity for metalinguistic reflection will perform to ceiling level. The aphasics performance will be affected by activation levels of the embedded hypotheses which in some cases will not reach recognition level.
- Activation will be constrained to some extent by the morphological structure of the polysyllabic words. The fluent aphasics do not generally present with morphological processing deficits so they should retain a differential processing between the monomorphemic and prefixed items.
- Schriefers et al.'s findings predict that the prefixed words will provide more solid lexical representations and offer the aphasic listener a more easily maintainable lexical item from which to extract the embedded target. The work of Taft et al. suggests that there will be an effect of frequency on the emergence of the embedded word as an independently segmented word.
- Orthography will help detection. Again the match between EW graphemic structure and that of the form it takes when in isolation will ease access to it. This would be of especial importance at a metalinguistic stage of processing when it would strengthen any representation which the aphasic needed to manipulate to engage with any embedded item.

The null hypothesis is that the morphological status (prefixed versus monomorphemic) of bi-syllabic words does not affect the detectability of words embedded at the end of bi-syllabic words. Furthermore, it states that the homographic/homophonic relationship between a word in its embedded form (e.g. trom*bone*, mar*quee*) and its form in isolation (bone, key), will not affect the embedded word's detectability.

6.2. Method

6.2.1. Paradigm

6.2.1.1. Off-line Embedded-Word Detection

In the current study, I use the off-line embedded word detection paradigm in an attempt to replicate, using aphasic versus ageing normal subject groups, Shillcock's (1990) cross-modal priming investigation. The cross-modal priming study compared the priming effects of word-final embedded words (EWs) in monomorphemic and prefixed bi-syllabic carrier words (CWs).

The experimental materials are adapted from those used by Shillcock but the paradigm for investigating activation differs. I examine post-lexical awareness of EWs. I propose that one can infer that embedded words which can be elicited after presentation of the carrier word, have reached a more accessible (salient) state of activation than those which cannot be elicited. In order to see the comparative accessibility of such words after neurological damage, I compare the post-lexical awareness of embedded words in aphasic and normal listeners. This procedure requires metalinguistic reflection on the materials. We do not therefore purport to assess any temporal relation between the activation of competitors, rather, to examine the effect of morphological context on lexical access.

The principal objectives are threefold: to investigate the activation levels of competing lexical hypotheses in words with varying morphological structure, to examine the effect of the graphemic relationships between competitors and to compare the processing of lexical alternatives in aphasics and normal subjects. Note that a high proportion of input in normal listening conditions for unimpaired listeners is underspecified. In order to recognise speech in real contexts more hypotheses than are eventually successful must be activated to eliminate the risk of missing the correct word parse.

6.2.2. Design and materials

This investigation aims to determine how morphological structure, and the grapheme-to-phoneme relationship between homophonic competitors, affect lexical segmentation and access.

The following 2 x 2 design was used: Morphological structure of bi-syllabic Carrier Word (2 levels; prefixed, monomorphemic) x Grapheme-phoneme relationship of embedded word to carrier word (2 levels; homographic, homophonic). Materials were crossed to produce 4 stimuli sets 1) Monomorphemic bi-syllables with a homophonic embedded word (*polite/light*), 2) Monomorphemic bi-syllables with a homographic embedded word (*trombone/bone*), 3) Prefixed bi-syllables with a homophonic embedded word (*descend/send*), and 4) Prefixed bi-syllables with a homographic embedded words (*report*). Each stimulus set contained 12 bi-syllabic materials, giving a total of 48 materials. A Weak-Strong metrical syllable structure was maintained across all materials. Each subject heard all materials.

The materials were randomised and interspersed with 29 filler tokens. The fillers were also bi-syllabic but did not contain word-final embedded words. Nineteen had no words embedded within (e.g. *regret*) and 10 had word-initial embedded words (e.g *cutlass*). This final precaution ensured that subjects would not adopt a strategy of attending solely to the second syllable when trying to detect embedded items. Ten practice items with the same specifications as the filler and experimental tokens were also generated.

The complete list of tokens was recorded by a female Scottish-English speaker using a Sony F1 Digital Audio Recording System in a sound-proofed recording studio. The tokens were presented to the speaker individually using a BBC-B micro-computer screen. This helped maintain a stable reading and avoided any list effect. See Appendix C for list of experimental tokens.

6.2.2.1. Response paradigm

Some subjects had deficits in word repetition or spontaneous word production or were dysarthric in addition to having impaired perception. A non-verbal response method was therefore required. One method which allowed us to maintain the internal validity of the experiment was to have a two-tier response; the first was an embedded word identification, the second, a picture pointing procedure. This second tier required the construction of picture boards. Pictures corresponding to the target items were scanned into an Apple Macintosh compatible image-scanner (Scanjet Plus) and onto Superpaint software. In addition to the pictorial representation of each target (i.e. *port* - in *report*), pictures corresponding to two phonologically related words (*porch, order*) were also scanned. Use of the scanner and paint package allowed manipulation of the pictures. This ensured that no extra-linguistic factors such as size, or definition influenced picture selection. The three graphics were positioned vertically on the page. Position of target in relation to the two fillers was randomised across materials.

6.2.3. Subjects

Two subject groups, normal and aphasic each contained nine subjects. The subjects in each group were matched for age, sex, socio-economic class and educational standard. The aphasics were selected because of recognised auditory and/or lexical level perception problems as measured by a standardised assessment battery modelled closely on the PALPA (Kay et al., 1988). The details of each aphasic subject's profile are given below in Tables 6-1 and 6-2.

6.2.4. Procedure

The set induction procedure (see Chapter 4, Pg 65) was used to prepare subjects for the experiment. A set of 8 practice materials preceded the test words. The practice items allowed the subjects to further familiarise themselves with the speaker's voice characteristics and the requirement of the experimental paradigm. The experiment proper followed. This involved presentation of individual bi-syllabic words to each subject auditorially over headphones. Subjects were asked to listen to each word. They were required to give a two-tier response. The first required a yes-no response; subjects were requested to state whether they could identify any small word within the two-

Table 6-1: Experiment 3: Aphasic Subject Linguistic Profiles - Results of Auditory Perception tests

Aphasic Subject Linguistic Profiles							
Name	*CVC Aud. Discrim.*	*CVC Non-word Discrim.*	*Aud. Lexical Decis.*	*Visual Lexical Decis.*	*Word-Picture*	*Aud. synonym matching*	*Score on Embedded Word Detection Test*
F I	.84	N/T	.80	N/T	.65	N/T	.33
E K	.94	N/T	.91	N/T	.78	N/T	.67
R W	N/T	N/T	.96	N/T	.96	.88	.43
J F	.79	N/T	.62	N/T	.63	.79	.45
B H	N/T	.60	N/T	N/T	N/T	N/T	.33
E T	N/T	N/T	N/T	N/T	N/T	N/T	.45
I E	.89	N/T	.89	N/T	.83	.87	.45
M W	.95	N/T	.78	N/T	.85	.43	.65
J YF	.96	N/T	.83	N/T	.85	.N/T	.35

syllable word they could hear. If the response was yes, they were asked whether the word they had heard matched any of the graphics on the picture board. The aphasic subjects were all familiar with these paradigms as both are used in the assessment battery administered.

6.3. Results

First I examined the responses from all eighteen subjects to establish whether the aphasics and controls were performing in distinct ways. A matched *t-test* showed that there was an effect of subject type ($t = 9.88$, $(d.f) = 8$, $p < 0.001$). Normal ageing subjects were significantly more successful than aphasics at recognising EWs.

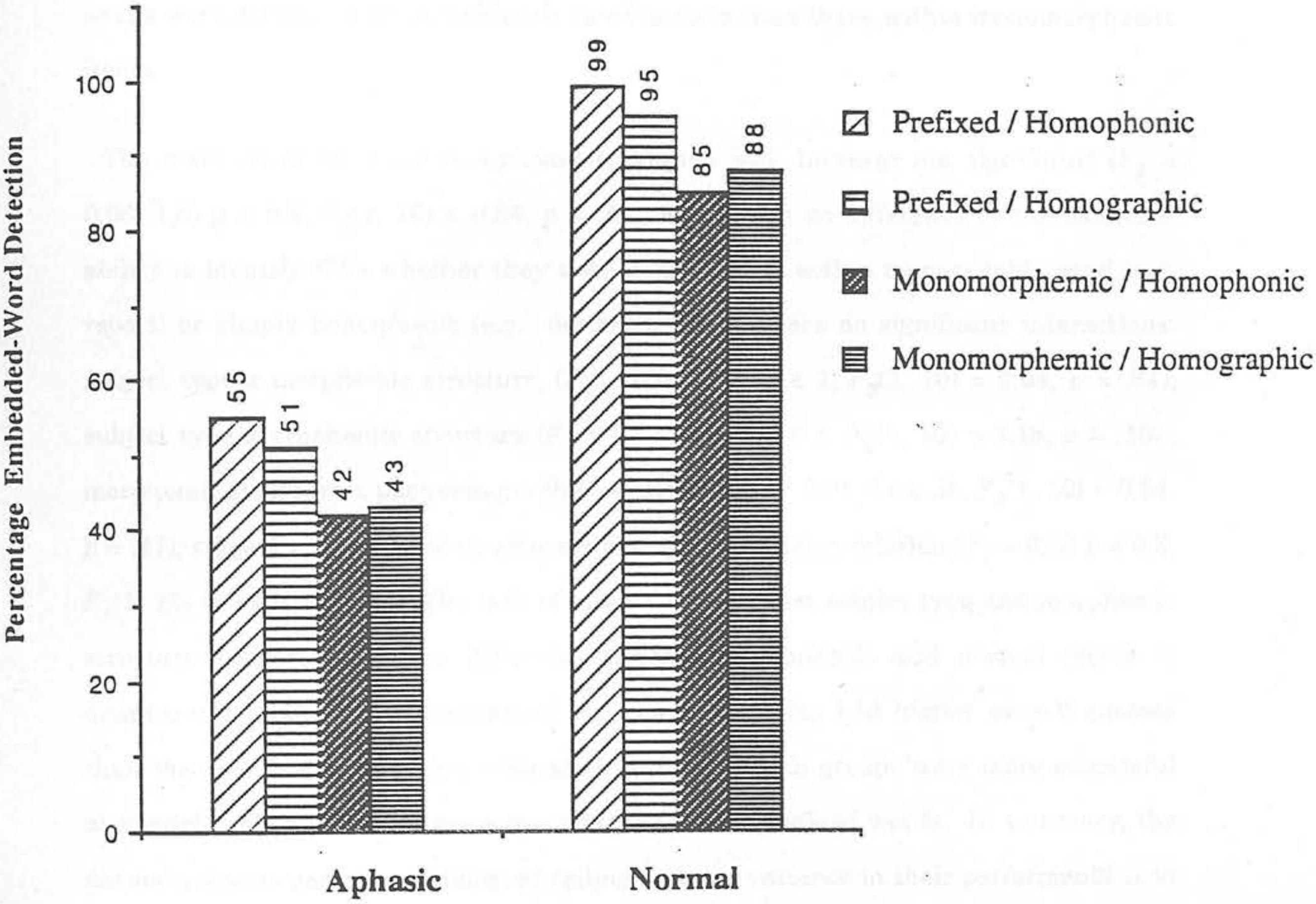
Next I considered whether the predicted independent variables were having a significant effect on the detection of embedded words. These questions were examined using a three-way ANOVA in relation to two-word class factors; *prefixed* versus *monomorphemic* and *homographs* versus *homophones* and one subject factor; *aphasic* versus *control*. (See Figure 6-1).

Table 6-2: Experiment 3: Aphasic Subject Profiles

Subject profiles						
Patient	***Sex***	***Age***	***Time Post Onset (months)***	***Aetiology***	***Occupation***	***Aphasia Classification***
F I	M	72	10	Left CVA	Engineer	Fluent
E K	M	48	10	Left CVA	Builder	Fluent
R W	M	45	13	Left CVA	Car Mechanic	Fluent
J F	F	69	23	Left CVA	Housewife	Fluent
B H	M	66	12	Left CVA	Engineer	Fluent
E T	F	52	19	Left CVA	Housewife	Non-Fluent[1]
I E	M	51	11	Left CVA	Retired Colonel	Fluent
M W	F	65	18	Left CVA	Housewife	Fluent
J YF	M	66	10	Left CVA	Laborour	Fluent

[1]See Table 4.2

Figure 6-1: Percentage detection of target word-final embedded words for Normal and Aphasic subjects.



	Aphasic		Normal	
Possible Total	46		46	
Mean	21	(46%)	41	(89%)
Range	17		5	
St. D.	6		1.5	
Min	15	(33%)	39	(85%)
Max	32	(73%)	44	(96%)

The main effect for subject type was significant (F_1 = 97.56 (1,8) $p < 0.0001$, $F_2(1, 10)$ = 195.89 $p < 0.0001$, MinF'(1, 19) = 65.13, $p <.05$). The main effect for morphemic structure was also significant (F_1 = 8.17 (1,8) $p < 0.02$, $F_2(1, 10) = 6.10$ $p < 0.05$, MinF'(1, 19) = 3.50, $p <.05$). The data showed that monosyllables embedded within prefixed words were detected with significantly more success than those within monomorphemic items.

The main effect for grapheme-phoneme relation was, however not significant (F_1 = 0.06 (1,8) $p = 0.8$, $F_2(1, 10) = 0.54$, $p = .47$. There was no difference in the listeners' ability to identify EWs whether they were homographic with a monosyllabic word (e.g. re*port*) or simply homophonic (e.g. de*scend*). There were no significant interactions: subject type x morphemic structure, (F_1 = 0.00 (1,8) $p < 1$, $F_2(1, 10) = 0.04$, $p = .84$); subject type x graphemic structure (F_1 = 0.04 (1.8) $p < 0.8$, $F_2(1, 10) = 3.18$, $p = .10$).; morphemic structure x phoneme-grapheme relation ($F_1 = 0.91$ $p < 0.36$, $F_2(1, 10) = 0.54$, $p = .47$); subject x morphemic structure x phoneme-grapheme relation ($F_1 = 0.03$ $p < 0.8$, $F_2(1, 10) = 0.11$, $p = .74$). The lack of interaction between subject type and morphemic structure suggests that the difference between the aphasic and normal scores is quantitative rather than qualitative; the normal subjects had higher overall success than the aphasics in detecting embedded words, but both groups were more successful at identifying words in the same contexts i.e. within prefixed words. In summary, the normal subjects performed almost at ceiling and any variance in their performance is in the same direction as that of the aphasic listeners. The ANOVAs computed did not reveal any further clues as to why the aphasic scores were generally lower than the normals.

6.3.1. Lexical Feature analysis

In order to explore further the differences between the two subject group performances I carried out a set of multiple regression analyses. This allowed me to examine the effect of lexical characteristics of the word sets used which could not be controlled *a priori*. The features examined were frequency of the carrier word, frequency of the embedded word, imageability, familiarity, and concreteness. Ratings for these features were taken from the MRC Psycholinguistic Database (Coltheart, 1981). Frequency values were taken from the standardised tables of Francis and Kucera (1982). The aphasic and normal data were analysed separately.

In each equation the dependent variable is the detection of embedded words. Individual independent variables were first correlated with the dependent variable. None of the correlations reached significance. This suggests that no variable is contributing in an outstanding way to the variance in the normal performance. Some of these variables were in themselves correlated. The only significant correlation was between imageability and concreteness ($r = 0.87$, *d.f.* $= 40$, $p < .001$). Subsequent analyses take this into account. Next multivariate regression correlations examined the effect on embedded word detection, of the combination of variables within each lexical item. A series of hierarchies were established. The first consisted of the following variables which were entered into the equation in descending order: embedded word frequency, carrier word frequency, imageability of embedded word, familiarity of embedded word. The second hierarchy substituted the difference between the embedded and carrier word frequencies for their individual frequencies as separate variables. The remaining variables were entered in the same order as in the first hierarchy.

6.3.2. Normal data

In the first set of hierarchies (using separate embedded and carrier word frequencies), the addition of concreteness to the equation contributes to a significant account of the variance. However, concreteness makes no unique contribution. Embedded word frequency, on the other hand, contributes to a significant unique account of variance. No other variables either contributed to a significant increase in the account of variance or made a significant unique contribution to any variance accounted for.

6.3.3. Aphasic data

For the aphasic subjects a very different pattern emerges. In the hierarchies in which embedded word frequencies and carrier word frequency are partialled out, the addition of imageability to the equation significantly increases the amount of variance accounted for. Further, imageability accounts for a significant unique portion of the variance. In the second set of hierarchies (in which <u>the difference between the embedded and carrier frequencies</u> is used), imageability contributes to a similar significant account of the variance. In addition, the variable representing the <u>difference between the embedded and carrier frequencies</u> is also significant. No other variables made significant contributions to account of variance.

In sum, the normal listeners were significantly better than the aphasics at detecting the overlapping monosyllabic hypotheses from within the presented polysyllables. For both groups the accessibility of the embedded word was greater when the carrier item was prefixed. Qualitative differences in normal and aphasic performance become apparent when lexical features of the embedded items are examined. For the normal subjects, frequency is a significant predictor of embedded word detection. The relationship between frequency and detection is not as straightforward for the aphasic listeners. For them, the size of the difference in frequency between the carrier and embedded word partially determines whether the aphasic will detect the embedded item. If the difference is large, detection is achieved. The best predictor of embedded word detection for the aphasic subjects, however, is the imageability of the embedded words.

6.4. Discussion and Conclusions

Aphasics are in general less adept at detecting EWs but it is striking that both subject groups detect EWs in prefixed CWs more successfully than in monomorphemes. For normal subjects, the features of cohort size, concreteness and familiarity do not themselves determine whether or not the listener will have difficulty detecting word final embedded words. Partialling out these factors (especially concreteness) reveals that the embedded word's frequency has an effect on detection of embedded words. The aphasic data show that concreteness/imageability of an embedded word does have a direct effect on whether the aphasic will detect it or not. The carrier and embedded words' frequencies are not in themselves effective in predicting detection of embedded words, but the difference between the embedded and carrier word frequencies is predictive of detection.

6.4.1. The prefix word advantage

One explanation for the present findings can be couched in terms of the prefix stripping arguments. Words which are affixed may simply be more open to introspection because of their being stored as stems (i.e. stripped of their prefixes). Detection of EWs in monomorphemic carriers would require more processing capacity because the relationship between the EW and monosyllabic competitor would be less transparent; both would take different stored forms. Seidenberg (1989b) considers such an account in the processing of visually presented complex words. He suggests that several experimental lexical decision results (Taft & Forster, 1976, Taft and Forster., 1975) reflected strategic response patterns rather than underlying processing differences; namely that subjects decomposed the carrier items into their component parts because it made the lexical decision task easier.

An analogous auditory processing account would explain the pattern of results for the aphasics. Although the prefixed words used as materials in this investigation were opaque prefixed words by definition, they were productive and more transparent than the monomorphemic words. According to an argument similar to that of Seidenberg, this would make such words more accessible for post-access decomposition. For the aphasic subjects we have already seen a suggestion that the performance data do, at least in part, reflect post access strategic processing in that the detection rates show an effect of imageability.

An alternative account for the increased detection of EWs in prefixed words would be to invoke cohort size: the prefixed words belong to larger initial cohorts. The CW would experience more competition from other contenders for recognition at word-initial level and would be less able to repress hypotheses emerging later in the word. Thus the lexical representation of the EW would be more easily detected by the listener because when it emerged as a potential match for the input, there would be no clearly winning competitor able to dominate it easily. The correlational analysis failed to reveal any evidence for such a hypothesis. The cohort size, as measured by the number of lexical items sharing the word initial segments, did not make any independent contribution to the account for the EW detection rates in either the normal or aphasic listeners. For the current set of materials, the data show no support of the cohort size competition hypothesis. Such a conclusion finds support from Bard and Shillcock (1992) who show that simple competitor set effects are confounded with word frequency and do not necessarily emerge independently.

There is a clear discrepancy between the current findings and those from Shillcock's (1990) work which report priming of words embedded within monomorphemic carriers and not those in prefixed words. This is an interesting contrast and may point to important differences in post- and pre-lexical effects active in the processing of these two types of words. Shillcock (Submitted) puts forward the argument that because prefix sequences (e.g. *repel*) are common strings, they are likely to be perceptually secure. He suggests that in the intermediate stages, the initial segments of the prefixed words offer secure possibilities for word hypotheses, which makes the emergence of final embedded candidates less appealing. Thus, *port* does not accrue a large amount of activation when *report* is heard. This same explanation could be adapted to account for the current data which reflect an element of post-access processing. The fact that the prefixed items offer perceptually secure lexical hypotheses could play a crucial role, especially for the aphasic listener, in allowing internal words to emerge.

The present results replicate Shillcock's findings that there is no aid afforded to emergence of embedded words by orthographic proximity. In this sense our findings are akin to the majority of other behavioural studies relating to orthographic facilitation of auditory word recognition. Even the aphasic subjects (who had no visual processing problems) did not show any advantage from orthographic match of the EW and CW. Given that they show effects for features such as imageability and a frequency effect, it would seem that orthographic match does not play a role in either securing lexical representations of auditorially processed words, or in increasing their activation levels.

6.4.2. Embedded word lexical feature effects

Turning now to examine the effects of the lexical feature variables we notice that there is a significant facilitation by the frequency feature for detection of embedded words by the control subject group. The higher the frequency of the CW the more likely the control subjects were to detect the EW. It would seem that the inhibitory capacity of the CW postulated by Frauenfelder is not operational at the post-lexical level. Given the small size of training corpus used to train TRACE and its failure to accommodate lexical feature information such as frequency and concreteness, we would not expect the TRACE findings to resemble behavioural data closely.

Seidenberg predicts that one might expect interference effects from stems in prefixed words when the stem morpheme corresponds to a common word (de<u>ride</u>) but not if the stem is rare de<u>ploy</u>. The normal data is only compatible to a certain extent with this prediction. The ease with which the embedded word emerged from its carrier environment was in part dictated by the frequency of the embedded word; but this was not restricted to the prefixed carrier items. Further, for the normal subjects in the auditory domain, I found no evidence of post-access strategies playing a significant role in the detection of the EWs. For the aphasics, who did show suggestions of post-access processing, the manipulation of the embedded words in the prefixed items was governed by the relative frequency of the carrier and embedded frequency.

For the aphasics however, the relationship between detection of the EW and lexical features of the CW may be too complex to be captured by such a crude analysis. Recall that aphasics showed no susceptibility to the frequency effect of CWs yet were greatly influenced by high imageability ratings of the EW. It may be that the aphasics were not treating the whole string (corresponding to the carrier word) as a real word but rather as a context in which to search for hidden words. In other words, they operate a metalinguistic strategy to enhance their processing of the embedded words. Thus there may be attenuation of the effect of the other lexical features (such as frequency) of the carrier word. The only EWs which would be activated would be those still present in the impaired lexical store; items most likely to survive would be those rating most highly on the imageability, scale.

A post-hoc investigation was conducted on one of the implications arising from the Frauenfelder and Peeters' simulations (1990); namely that final EWs reach higher activation when they are in CWs whose initial segment is a word rather than a non-word. In the present study control subjects reported that several materials had initial EWs in addition to the planned final EWs: *champagne* containing *sham+pain*. Frauenfelder and Peeters predict that the *pain* in *champagne* would be more 'activated' and by inference more readily detected, because of the presence of a word initial EW. A correlational analysis, however, failed to show a significant effect for either subject group. At the post-lexical stage of word recognition, the presence of an earlier short lexical hypothesis does not affect the salience for the listeners of late embedded lexical hypotheses.

In conclusion, the results of this off-line investigation into the post-access salience of embedded lexical results, tally with a notion that listeners do have access to some structural information of prefixed words which morphologically less complex items do not have, and which facilitates emergence of EWs. Those lexical hypotheses which are activated in prefixed words retain activation at the post-lexical stage to a greater extent than those in other morphological structures. The implication for segmentation from this would be that for normal processing, prefixed words allow the emergence of other candidates for positing word onsets more readily than monomorphemic words. Further, these data indicate that the frequency of competing hypotheses is influential in their activation as word candidates. This will be explored more fully in the following chapter.

Interestingly, the activational difference between the words embedded within prefixed and monomorphemic words for the normal subjects is paralleled but more pronounced in the aphasic listeners' performance. The frequency effect is, however, not evident in any simple form. There is a clear implication, however, that aphasics have a mechanism with which to entertain conflicting word hypotheses. In addition to the automatic processing which would ensue in real-time, the aphasics engaged in a metalinguistic contemplation of alternatives which was facilitated in the contexts where the alternative candidates were highly imageable.

Chapter 7

Relative Frequency of Lexical Hypotheses: The effect on normally aged and aphasic segmentation

7.1. Introduction

The following chapter reports an investigation into competition for lexical access and subsequent word boundary allocation in cases where the speech signal presents overlapping hypotheses for interpretation of the sensory input. I consider how words which share initial segments compete and affect successful access of a target word. In particular I examine how the frequency of the targets and their overlapping competitors interact and affect lexical access. I compare the performance of normally ageing listeners with that of a fluent aphasic in processing a speech stream which, at initial stages, offers both monosyllabic and polysyllabic matches. I investigate the effect of the lexical characteristics of the partial matches on early segmentation (that is, choosing to match the input to monosyllabic candidates) as opposed to late segmentation (which would entail the listener proposing polysyllabic hypotheses).

7.2. Word recognition in connected speech

Because all languages are made up of few distinct phonemes and many lexical items, all words in any given language share some phonetic material with others. It follows then, that the sensory information in any speech stream offers multiple lexical access possibilities. I consider here how the allocation of word boundary is made.

7.2.1. Sequential Analysis

Claims supporting sequential processing are now mainly considered untenable. Luce (1986a) finds that 38% of word types are not unique at their offset.[1] Further, he shows that this 38% contains many of the most frequent words in the lexicon which increases the incidence of 'overlapping' words heard by the listener. Shillcock (1990) suggests that even this figure is an overestimate of the number of words which are truly unique at their offset and cannot be continued to form a further lexical item. If one takes into account inflectional suffixes, it is clear that even words for which there is no 'unrelated' possibility for continuation (such as *trespass* which becomes unique at *tresp*) location of the word juncture after *trespass* may be wrong as the target item may be *trespasses* or *trespassing* or *trespassed*. The crowding of phonetic space seems even more dense when one considers that 94% of English polysyllabic words have other potential lexical items embedded within (McQueen & Cutler, 1992). The problem that this presents for listeners is not inconsiderable: 1 in 5 of words are not identified until after their acoustic offset (Bard et al., 1988). Finally, it is found that initial parts of words activate other candidates whose initial segments match that portion (Zwitserlood, 1989). Data from other languages shows that this phenomenon is not restricted to English; in Italian strings such as *visi tediati* elicit priming of words related to *visite* when *visite* but not the entire phrase has elapsed (Tabossi, 1993).

7.2.2. Simultaneous Analysis

Given that sequential analysis would be hindered by the complexity of non-unique word offsets, models espousing simultaneous consideration of overlapping lexical hypotheses have come to the fore. Models which support the concept of multiple activation of hypotheses, such as Cohort (Marslen-Wilson, 1987, Marslen-Wilson, 1990) and TRACE (McClelland & Elman, 1986) recognise the need to consider numerous candidates for recognition and the fact that, because multiple hypotheses are initially activated, there must be a means by which one candidate emerges for recognition. Although Cohort and TRACE differ in many crucial aspects, both allow the processor to entertain multiple transient candidates for recognition; both allow for candidates to

[1]Based on a statistical analysis of 20,000 American English words.

have different chances of being adopted as the percept and both provide a means by which one candidate can come to dominate all others. These fundamental properties are usually described using the metaphors of activation and competition (or inhibition).

7.3. Mechanisms involved in candidate selection for lexical access

7.3.1. Activation in Cohort

The review of the recent literature on activation and competition of word candidates given in Chapter 2 shows that most current models of spoken word recognition instantiate mechanisms which are intended to account for the emergence of a single word from a pool of potential candidates. The Cohort model (Marslen-Wilson, 1987, Marslen-Wilson, 1990) supports the claim that sensory input causes the excitation of a pool of mental representations of words. All hypotheses whose word initial portions match the sensory input enter a pool of contenders for identification of the word. In recent investigations which aimed to establish the 'microstructure' of word recognition, Marslen-Wilson posits that all and only representations which precisely match the input are activated: deviation by a single feature would preclude a representation from entering the cohort in first pass processing. Mismatches which results in a nonword (such as *pomato* for intended *tomato*) disrupts activation of a target word (*tomato*), but this mismatch is recoverable; the intended representation can be retrieved in the proposed second pass processing. Earlier work (Lahiri & Marslen-Wilson, 1991) has shown that predictable variance from the precise target phonology does not suppress activation; gating studies show that presentation of words like *ban*, which has a nasalised vowel, engenders *bad* as a member of the response cohort. Marslen-Wilson posits, therefore, that variation from the target which is 'phonologically legal', does not count as deviation and therefore will not hinder activation of target representations. The Cohort Model predicts that the array of activated competitors share a precise set of word initial characteristics; any variation from strict phonological match is predictable variation.

It is from this initial group of competitors that one candidate emerges as a match for the input. Take for example the beginning of an utterance */pju.../*. At this point in the speech signal, a cohort of approximately 20 words will be activated, including PURE,

PURITY, PURITAN, PURIFICATION, PUERILE, PURIFIER, PUREE. Although these words have the same word initial syllable, their offsets vary. If the word spoken is PURE, the speaker intends that the listener segment the signal at */pjur/*. The target may, however, be PUERILE, in which case there needs to be a mechanism to make it possible to consider longer and shorter hypotheses coupled with an effective way of chosing the intended segmentation as quickly as possible. I consider here how these multiple activated candidates compete for recognition and try to establish which lexical characteristics facilitate the recognition of overlapping candidates.

7.3.2. Competition in Cohort

Competition amongst the varying candidates is conceptualised by the Cohort model as an indirect process. Each candidate is activated to a level commensurate with its similarity to the sensory input. This activation strength is governed by the degree to which the sensory features of the candidate correspond to the input and a frequency dictated probability that a particular representation matches the input. Word frequency is a well attested determiner of recognition latency whether in increasing activation strength or lowering recognition threshold. At early stages of processing, the relative probability of candidates matching sensory input dictates the activation level of candidates. As the signal proceeds acoustic information indicative of polysyllabicity is received and the earlier favoured monosyllabic guesses become less attractive. The Cohort Model supports the prediction that the polysyllabic hypotheses accrue activation until one reaches a level of activation criterially different from all other competitors. This is the point of recognition. In this investigation my chief interest lies with the adoption of competitors rather than the endpoint of recognition.

7.3.3. Activation and Competition in TRACE

Other genres of model support a more direct competition between activated candidates. TRACE, for example, posits that the perception of sensory information by the listener activates an array of potential matches. It differs from Cohort in that the 'match' decision is not restricted to words which resemble the target in the word initial portion but rather extends to competitors which match on an overall goodness of fit metric. Once the set of candidates is excited, competition ensues by means of lateral inhibition. Word hypotheses which are initially good candidates increase their lead over less attractive competitors by inhibiting them. Lateral inhibition also has the effect of changing the relevance of the cohort characteristics. Imagine the case where the target is in fact a rare word. Initially candidates which are compatible with the sensory input would enter the competition for recognition. Likely candidates (among which would number frequent words) will receive more activation than less probable ones. As more sensory input is received, even some of the more frequent competitors will drop from competition when their match to the sensory input deteriorates. Of those that are still compatible with low level information, the more frequent competitors will be most activated and will actively suppress the emergence of the rarer hypotheses. As the more frequent competitors are more highly activated and have increased their lead over less likely candidates through inhibition, one would predict that it would take longer to oust such candidates from their lead, even when acoustic information is received which decreases the probability of their candidature. TRACE supports the notion that the more competitors that are of higher frequency than a low frequency target, the more the low frequency target will be inhibited. So, rare targets from dense neighbourhoods of frequent words will be more inhibited and therefore take longer to rise than targets with fewer higher frequency competitors. Bard and Shillcock (1993) point out that the frequency of the most frequent competitor hypothesis makes the same predictions. They find a large correlation between the frequency of the most frequent member in a competitor set (cohort) and the number of competitors in that cohort; very high frequency items tend to exist in large cohorts. This intercorrelation makes it difficult to independently study the effect of either of these features.

7.3.4. Other competition data

McQueen & Cutler (submitted) report, *inter alia*, an auditory word spotting task in which they test the ease of detection of words embedded in nonsense words. The target words are embedded within nonsense items of two lexical types; those comprising the beginnings of real words like *sacref*, which is the beginning of *sacrifice*, and those not starting any real word like *sacrek*. In both cases the target word is the same i.e. *sack*. Although the target word is always a strong syllable, in some cases it is embedded within words with a Strong-Weak prosodic pattern, as is the case with the above example *sacrek* or *sackref* but in others it occurs in a Weak-Strong structure so that the target is at the end of the nonsense item e.g. *mess* in *demess* (in *domestic* and the nonword *nemess*). McQueen and Cutler found that word-initial items embedded within two-syllable nonsense strings are more quickly spotted if the string is not the in a real word (e.g. *sacrek*, *nemess*) than when it is (e.g. *sacref* and *demess*). The competition effects were found to be larger for WS strings like *demess* than for SW strings like *sacref*.

When a target like *mess* occurs in a WS string like *demess* it occurs late in the nonsense item, by which time the competitor *domestic* has had chance to accrue activation and can inhibit the emergence of the target, *mess*. In SW contexts like *sacref*, the target word is in initial position and itself accrues activation before the competitor *sacrifice* has much chance to inhibit it.

The materials in the present investigation are all strong syllable initial. McQueen & Cutler do not explicitly control for frequency of target and competitor but an unequal-n ANOVA failed to show a significant frequency effect for detection latency. They suggest that the stress and competition effects may have clouded any frequency effect present and do not rule it out. They do not comment on the potential interaction of target and competitor frequency effects. They do not acknowledge the fact that until the offset of the target item, both sets of stimuli activate cohorts containing the target and the distractor and it is only at the last segment of the non-word nonsense items like *sacrek*, that sensory information disconfirms the bisyllabic hypothesis. That is, even when the stimuli is *sacrek*, at the point where only *sacre* is heard, the word *sacrifice* will have been activated.

7.4. Frequency effect bias in candidate activation

Word recognition is in part driven by bottom-up matching of sensory input onto internal lexical representations. The activation strength of the competing hypotheses is thought to be governed in part by degree of match of a lexical entry to the sensory input from the speech stream. Once a lexical entry has entered the pool of contenders for recognition, lexical characteristics of the competing hypotheses, like frequency, are thought to affect the speed with which potential matches rise to recognition. The present investigation focuses on the situation where the initial portion of the sensory information equally well matches two candidates which differ in length and frequency. With the influence of sensory matching thus controlled, I will examine how the frequency of lexical competitors affects lexical processing.

7.4.1. Normal frequency effects

Frequency is the lexical characteristic most often posited as having an influence on word recognition accuracy and latency. The major findings pertaining to frequency effects in processing are described in Chapter 2. The large part of the literature suggests that word frequency has a great effect on the competition between acoustically appropriate candidates for word recognition, (Marslen-Wilson, 1990, Segui & Grainger, 1990, Andrews, 1989, Whaley, 1978, Frederiksen & Kroll, 1976, Forster & Chambers, 1973, Monsell, 1985). Listeners respond more quickly and accurately to frequent words than they do to rare ones. Gating studies confirm the perceptual advantage of frequent over rare words: less word onset information is needed to identify frequent words out of context than rare words (Grosjean, 1980) and in pre-recognition stages of processing, responses to stimulus identification tasks are predominantly frequent words as opposed to contextually appropriate words, for instance (Tyler, 1984). Note, however, that McAllister (1990) reports some contextual effects.

7.4.2. Frequency effects in aphasia

Work with aphasics has shown that even after some cerebral trauma, speakers and listeners typically find frequent words easier to process (Schuell et al., 1961). Detailed study of the literature, however, suggests that there is not a uniform retention of a 'normal' frequency advantage for all aphasics in all linguistic tasks. Non-fluent aphasics seem to retain a sensitivity to the frequency characteristics of words more than fluent aphasics do in word meaning retrieval tasks (Lesser, 1978). On the other hand, it has been found that fluent aphasics, like normals, show a frequency effect in lexical decisions to open-class words, but not to closed-class words. Non-fluent aphasics show frequency effects for both open- and closed-class words bias in lexical decisions to closed class words (Bradley et al., 1980). Such findings are, however, controversial; some researchers (Segui et al., 1982, Gordon & Caramazza, 1982, Gordon, 1983, Segui et al.,

1987) have not been able to replicate this result for aphasics and others (Segui et al., 1987) failed to find any frequency effect for any very high frequency words whether they were open- or closed-class.

7.5. Locating frequency effects within processing

Attempts at locating the stages of the word recognition process in which frequency of words is influential, has spawned much literature. In this chapter I am chiefly concerned with the role played by frequency in the competition between activated candidates in strings which initially present more than one potential match with the input.

Evidence from various experimental paradigms converges on the notion that for normal listeners, word frequency strongly influences the activation of hypotheses and speeds their recognition. Lexical decision tasks typically show faster decision times for frequent words than for rare ones (Frederiksen & Kroll, 1976, Besner & McCann, 1987, Paap et al., 1987, Forster & Chambers, 1973).

Naming of high frequency items is also accomplished faster than naming of rare words. When the listener is forced to delay the naming response until a time commensurate with that assumed necessary for lexical access to have occurred, i.e. 100-300 ms (Rayner, 1977(reported in Balota and Chumbley, 1985)), frequency effects still obtain (McRae et al., 1990, Balota & Chumbley, 1985). Interestingly the advantage of the frequent items diminishes when longer delays are enforced (McRae et al., 1990)[2].

Although frequency effects are well attested, the research reported above leaves unanswered the question of the manner in which frequency affects recognition; whether frequent words have lower thresholds for recognition which makes reaching recognition thresholds easier, or whether the activation of frequent items rises faster than that of rare words thereby reaching the recognition point more rapidly. At pre-recognition stages of processing frequent words show an advantage compared to rare words. Gating study data show that at early gates, frequent guesses predominate regardless of the

[2]Note that Balota and Chumbley (1985) report frequency effects in the longer delayed conditions but McRae et al.'s work suggest that the former results were due to articulatory differences between the frequent and rare words used. See Chapter 2 for discussion.

target word frequency. A sizeable amount of evidence, however, (Marslen-Wilson, 1990, Monsell et al., 1989) does show that activation is affected by frequency. It is unlikely that in a recognition system "frequency of experience is not somehow reflected in the basic organisation of how the system responds to sensory inputs" (Marslen-Wilson, 1990, Seidenberg , 1989) suggest that activation rate is indeed affected by frequency.

It is not easy to predict how much advantage frequent competitors enjoy over rare ones in aphasic processing. Here I focus on what kind of advantage is claimed by frequent polysyllables as opposed to rare polysyllables in their emergence as candidates for recognition when they are competing against other overlapping frequent and rare hypotheses. This entails determining whether there is a frequency advantage at this pre-recognition stage of processing.

7.5.1. Frequency and competing hypotheses

Under the assumption that activation levels are affected by frequency, it is important to consider how the activation patterns of competing hypotheses affect emergence and recognition of target words. Marslen-Wilson addresses this issue (1990) in a series of investigations in which he compares activation and recognition patterns of targets and competitors which are controlled for frequency. Lexical decision, auditory repetition, and recognition point analysis from a gating experiment show that target word frequency affects recognition latency. Competitor word frequency effects, however, fail to emerge; frequent targets are recognised quicker than rare words whether their competitors are frequent or rare. Cross-modal priming data and isolation point[3] data from the gating study showed effects of both target and competitor word frequency. The isolation points for frequent targets were earlier than for rare targets. In addition, both sets of targets were more delayed when they had frequent competitors than when they had rare competitors. The priming study yielded comparable results: there were competitor frequency effects but only when the probe was presented early in the word. That is, effects of the frequency of the competitor items were felt only at points where the signal had not yet disambiguated the competitor from the target word.

---

[3]The Isolation point is the average point where the listener begins to identify the target item correctly.

Marslen-Wilson reconciles this array of results by appealing to the transience of frequency effects. At a point where the acoustic information given to the listener is not sufficient to disambiguate between the target and competitors, (i.e. the target and competitors share the same sensory information up till that point) the listener is not in effect hearing the target, but, with regard to sensory input, perceiving the possibility of the target and its competitors equally. When the target is no longer ambiguous, as is the case at the point of recognition, the effect of competitor frequency has dissipated or balanced out so that the difference between frequent and rare competitors is not relevant. At the isolation point the identity of the intended word is not clear, there is still ambiguity between the target and other competitors from which the target has not yet diverged. In these cases the competitor frequency affects the resolution of the target word identity. This data on the relative role of competitor frequency depending on ambiguity of the signal has important implications for predictions for the current investigation. I am chiefly interested in the strength of the listeners' decision not to posit the end of a word but to adopt, instead, a polysyllabic parse for the acoustic signal. The point at which the signal offers a polysyllabic hypothesis (e.g. at *curi* in *curious*) is referred to as the poly-point. At the poly-point, the frequency effect of both competitor and target words will be salient as the sensory information will not have disambiguated the competitors. Typically, discussion of target and competitor interaction has referred to activation of competitors, for example, *bad*, when the target is a phonologically similar word like *pad*. The status of candidate identity is different when lexical hypotheses overlap. Overlapping competitors share sensory information; PURE and PUERILE share the sensory information "*pjur*". Up to the point *pjur*, the sensory input equally matches either of the lexical representations[4].

[4]A phonetic variation between canonical representations of PURE and PUERILE will be of the sort described by Lahiri and Marslen-Wilson as redundant and therefore not treated as deviation so will not be the cause of any differential activation of the lexical candidates.

7.6. Predictions for segmentation by the normal ageing subjects

7.6.1. Trace predictions for competition

Activation of erroneous hypotheses is a necessary component of architectures which need to cope with unclearly bounded lexical items. Several predictions for segmentation emerge from consideration of TRACE and of data collected from simulations using a two word lexicon in a TRACE model with only bottom-up information flow (Frauenfelder, 1990). Frauenfelder and Peeters investigated the interaction of competition and lateral inhibition when the competing overlapping hypotheses consisted of a short word embedded within a longer word. The simulations used a restricted lexicon which did not take frequency into account.

Simulations using one word lexicons (i.e. words did not have any competitors) showed that long words (e.g. *carpet*) always achieved higher activation than short words like *car*. When competitors were introduced, (i.e. the lexicon consisted of more than one word; e.g. *carpet* and *car*) the longer word advantage is maintained but activation levels of target words are attenuated through competition. When the longer, Carrier Word (CW) is the target item, the Embedded Word (EW) (*car*) is initially the more strongly activated but falls rapidly when polysyllabic information is given. Note that these simulations are without frequency bias. They provide a partial prediction, therefore, for cases where target and competitor frequencies are equal; that the EW activation will initially dominate that of the CW, but will quickly attenuate when polysyllabic sensory information is received.

When the Embedded Word (e.g *car*) is the target, the short word hypothesis retains its initial lead but does not exert much inhibition on the long word competitor which it dominates. When the segmentation choice is between one long word, for example *carpet* and two short word, e.g. *car & pet*, lateral inhibition stops the short word hypotheses winning. As activation is largely governed by match between phonetic input and potential targets, longer words, which contain more phonetic material than shorter words, accrue more activation and stay more activated than their shorter competitors. The longer word advantage is further enhanced by its lateral inhibition of competitors. With a larger (more realistic) lexicon, longer words attract more competitors as they consist of lots of short strings of phonemes which comprise all or part of other words. Competition within this large set of activated words gives the short word an opportunity to rise to recognition level. The principles behind the connectivity within TRACE are, however, not necessarily realistic and the current instantiations do not incorporate frequency effects. This limits the usefulness of any predictions it can make for natural processing. In general, when activation is assumed to be affected by frequency of alternative hypotheses in word initial position, the most frequent hypothesis would accrue most activation until the offset of the short word. At the offset of the short, embedded word, the longer hypothesis would build up activation and eventually suppress the shorter hypotheses.

7.6.2. TRACE predictions for emergence of polysyllabic hypotheses

Early versions of TRACE (1986) accommodate the way that frequency affects the emergence of alternative lexical hypotheses in one of two ways: variation of word resting or threshold levels according to frequency, or variation in strength of the connections between the phoneme and word levels which increased the speed of activation of candidates. The TRACE model incorporates lateral inhibition, and therefore supports the prediction that if a stimulus has a strong competitor, the competitor inhibits the activation of the target, lowering its activation level and thereby delaying recognition. When listeners are presented with polysyllabic words, how does the polysyllable emerge? What will be the effect of the frequency of the target (polysyllabic) word? If frequency affects recognition by engendering a steeper rise in a candidate's activation curve, then one would predict that frequent polysyllables would emerge faster as likely candidates than rare polysyllables.

Let us now consider the interaction of competitor activation and inhibition. When the polysyllable has rare competitors these will rise in activation slowly, the polysyllable will receive little inhibition, and will thereby become a stronger competitor itself. If a polysyllable of equal frequency has strong competitors, which provide stronger inhibition, its activation would be weaker and therefore less able to inhibit its competitors in turn. With lateral inhibition, (see Table 2-1) weak competitors have little or no affect on the activation pattern of competing strong targets but have some affect in stunting the activation of weak targets. Strong competitors have some effect on strong targets but more effect on weak targets. Without lateral inhibition, (see Table TABLEACTB) the activation curve of the target is not affected by competitors. The relational effect between competitor and target frequency results only from the difference in activation strengths between competitors and targets and the fact that strong competitors delay the point at which strong targets can so exceed this in activation as to reach some criterial difference. In short, with lateral inhibition, one should witness the influence of both monosyllable and polysyllable frequency in the emergence of the polysyllabic hypotheses.

In this experiment listeners are presented with strings for which overlapping polysyllabic and monosyllabic hypotheses are contenders. We are interested to see how the strength of competitors, as predicted by frequency, effects the pattern of emergence of the longer hypotheses. It is difficult to make predictions in terms of the effect of target and competitor strength, as, at the divergence point, both monosyllable and polysyllable are equally well matched to the sensory input; the concepts of target and competitor can only usefully be employed from the post-recognition/divergence standpoint.

7.6.3. Cohort predictions

The Cohort model is a model which does not incorporate a lateral inhibition mechanism. It supports the prediction that weak competitors play a similar role in processing regardless of target type; the rare monosyllables will delay emergence to the same (very limited) degree when embedded in a rare and frequent polysyllable. Rare monosyllables provide weaker competition than strong monosyllables, but rare monosyllables compete equally against rare and frequent polysyllables. Frequent monosyllables also compete equally with polysyllables of different strengths. The data presented by Marslen-Wilson (1990) showed that when targets are ambiguous, transient competitor frequency effects are felt. The materials to be used in the present investigation will all be ambiguous in that all of the polysyllabic target words share phonetic material with a monosyllable. At the point of offset of the monosyllable, there is always a lexical possibility for continuation or segmentation. The listener is presented with a stream which is ambiguous as to its syllabicity until after the point of offset of the monosyllable. Such results predict that the emergence of polysyllables will

Table 7-1: Models Incorporating Lateral Inhibition:
Predictions for activation patterns of target and competitor items

Activation Patterns	
Stimulus type	*Predictions*
Rare Monosyllable - Frequent Polysyllable	Frequent polysyllabic hypotheses will emerge quickly, because the weak monosyllabic candidate will not inhibit the polysyllable when polysyllabic sensory information is perceived. That is, they will have an early poly-point. Because the polysyllable receives little inhibition, it will rise quickly, effectively inhibiting other competitors and attain recognition swiftly. That is, it will have an early isolation point.
Frequent Monosyllable - Frequent Poly	Frauenfelder and Peeter's TRACE simulations suggest that when hypotheses are matched for frequency, the monosyllabic competitor will initially be more highly activated. It will inhibit emerging polysyllabic sensory matches; the poly-point will be delayed in relation to the case where the monosyllable is rare. As further acoustic information is received, strong polysyllables accrue activation because this additional phonetic material matches the input and they come to inhibit the monosyllable. The emergence of the strong polysyllable will be slower than when the competitor was a weak monosyllable.
Rare Monosyllable - Rare Polysyllable	Neither the target monosyllable or polysyllable will be very well activated. As they are matched for frequency, the monosyllable will be initially more activated but will not inflict much inhibition on the polysyllable. The polysyllable should therefore emerge fairly rapidly, but not as quickly as the frequent polysyllables which have swifter rise times.
Frequent Monosyllable - Rare Polysyllable	The frequent monosyllable will be highly activated initially because of its monosyllable advantage and its frequency advantage. This monosyllable will exert extensive inhibition on the polysyllable and delay its emergence considerably.

be dependent not only on the polysyllable (target) frequency but also on that of the monosyllable (competitor) frequency.

Bard (1990) claims that the crucial difference between the predictions made by models which incorporate inhibition and ones which do not is this: without lateral inhibition the target activation level is not altered by the presence of, or strength of, competitors. Any relational effects exhibit themselves through delaying the point at which a target

Table 7-2: Models Without Lateral Inhibition:
Predictions for activation patterns of target and competitor items

Activation Patterns	
Stimulus type	*Predictions*
Frequent and Rare Polysyllables - Rare Monosyllables	Rare monosyllables will delay the emergence of polysyllables minimally whether the polysyllable target is frequent or rare, but as the frequent polysyllable will be activated more quickly, it is predicted that it will emerge faster than rare polysyllables with rare monosyllable competitors. There will be an effect of polysyllable frequency where competing monosyllables are rare.
Frequent and Rare Polysyllables - Frequent Monosyllables	Frequent monosyllabic competitors are predicted to delay the emergence of polysyllables to a greater extent than the rare monosyllables.

attains a criterial advantage over competitors which is necessary for recognition. With lateral inhibition the activation strength of targets and competitors actively alter each others activation curves. Consequently, without lateral inhibition there should be a competitor frequency effect (and therefore earlier poly-points for rare than with frequent monosyllabic competitors) and a target frequency effect (poly-points earlier with frequent than with rare polysyllabic targets) but no interaction. With lateral inhibition, on the other hand, all three effects are predicted. Studies like this one allow us to decide which of the two systems operates in processing.

7.6.4. Predictions for normally ageing adults

Priming studies of normal ageing adults' lexical access (Stern et al., 1991) showed similar priming patterns to that of college aged subjects. This suggests that the rapidity of automatic access to lexical information does not diminish substantially with age. Stern et al. attribute any difference in processing time in ageing adults to degradation in central processes. This finding is at variance with that of Howard (1986) who did find an ageing effect. The measure he used, however, did not tap into the automatic processing investigated by Stern. It is not clear that any direct predictions can be made about ageing subjects which would differ substantially from those made about younger non-impaired subjects.

7.6.5. Predictions for activation and recognition by aphasic listeners.

Little work investigating the emergence of competing hypotheses has been conducted with aphasic listeners. Milberg, Blumstein and Dworetzky (1987) found that lexically ambiguous items are processed differently by fluent and non-fluent aphasic subjects. Subjects were presented with triplets consisting of words and non-words. They were asked to make a lexical decision to the third word. The crucial triplets were of three types. First, concordant triplets in which the second item has two meanings, but where both the third and first word are associates of the same meaning of the second word (e.g. *tool, pick, shovel*). In this example, *pick* has at least two meanings, *digging implement*, or *choose*. Both the first and third words are related to *digging implement*. Second, discordant triplets in which the second item again has two meanings but the first and third word are associates of different meanings (e.g. *choose, pick, shovel*). The third set were unrelated triplets. The Wernicke's (fluent) aphasics, like the normal controls, were found to show priming for concordant lexical items. Milberg and Blumstein suggest that this reflects a selective activation of only the semantically related meanings. They showed no facilitation for the discordant cell. The Broca's (non-fluent) subjects failed to show priming in any condition. Their performance was interpreted as being indicative of a difficulty in accessing any lexical representations of words. An equally plausible account of the data would be that the correct lexical representations were accessed but not quickly enough to show facilitation of related items. The fact that the overall lexical decision time is delayed compared to normal adds credence to this delayed rise-time hypothesis. That semantically unrelated items (that is, the discordant condition) do not facilitate priming could indicate that the irrelevant, non-semantically related hypotheses are dismissed more quickly than the related hypotheses or that activation of polysemous words is not as extensive as it would normally be.

A further study by Milberg et al. (1988a) reports that fluent aphasics show priming from phonologically related words but that priming does not necessitate sharing of word-initial features; overall fit is sufficient (specifically vowel and consonant rhyme). This is at variance with claims made by Marslen-Wilson et al. whose data from normal subjects show that rhyming words do not prime each others' associates (Marslen-Wilson, 1990). Non-fluent listeners only showed priming with phonologically and semantically related real words. Swinney et al. (1989) and Prather et al. (1991) concur with the abovementioned finding that Wernicke's aphasics show 'normal exhaustive access patterns'. Prather et al., however, suggest that Broca's aphasics' failure to show priming in the investigations is due to slow rise time or activation of competitors.

In the light of the above findings it would seem more plausible to posit that aphasic lexical impairments have their provenance in a more distributed faulty interaction of candidate lexical hypotheses rather than in specific lexical deficits. There are several possibilities as to the manifestation of this impaired functioning. The aphasic literature does not allow convergence, with any certainty, on one prediction for the present experiment. Even if we restrict the predictions to those based on broad activation and competition impairments, the following possibilities are still tenable.

1 The right candidate (target) will not be activated at all and therefore will not be recognised. If phonological material is not processed normally the wrong word initial cohort will be activated and the target could not be found. If only a restricted part of the cohort is activated (e.g. the most frequent members) less frequent candidates could not emerge.

2 The target is activated but not as strongly or swiftly as normal. If the right cohort is accessed but the aphasic listener is impaired in processing the information which confirms a particular candidate , then the target may never accrue sufficient confirmation to be recognised.

3 The competitor candidates are activated too strongly. A competitor candidate which is strongly activated because of its frequency may dominate the target because the target is not confirmed from other information sources.

Berg & Schade (Berg and Schade, 1992) offer an activation/competition view of aphasic processing impairment. They suggest that the excitatory and inhibitory activity moving through the processor is "reduced compared to unimpaired processing". Errors are couched in terms of 'hyperactivation' or 'hypoinhibition' (under-inhibition). Under-inhibition is considered the interpretation most compatible with the behavioural data. Berg argues that hyperactivation of hypotheses would predict anticipatory perseveration in production; this phenomenon is not widely reported (if at all). It is also reported that when perseveration in production occurs, the initial rendition of the perseverated item is not usually produced at normal speed (Buckinhgham, 1979) as would be predicted by hyperactivation. Further, Berg's argument against hyperactivation implies that if errors in production or perception are due to the excessively quick or high activation of strong competitors, then one would expect to find at least normal production or recognition rates of lexemes which are (inter alia) the highest in their cohort. The assertion that perseveration data contradict a theory of hyperactivation rests on the assumption that abnormally high activation would manifest itself as very steeply rising activation resulting in abnormally quick word production. This is not necessarily so. A hyperactivational account of perseverations could be defended if one assumes that the hyperactivation manifests itself in a maintenance of recognition level activation long after normally processing items. In other words that a normally activated word, reaching production threshold at a normal rate, simply maintains its production activation level and does not fall (by decay or inhibition) in the normal way. This notwithstanding, evidence from other areas of cognitive processing suggests that under-inhibition is the more likely provenance of aphasic impaired processing. Perseverated words may only appear to be hyperactivated because they have been under-inhibited or not decayed when they are no longer viable or useful.

I predict that for the fluent aphasic in this present experiment, initially activated hypotheses (monosyllables) will be activated sufficiently to surface as elicited responses. The polysyllabic hypotheses rise in activation, possibly more slowly than in normal processing, but the crucial difference between normal and aphasic performance is that the polysyllables do not receive the kind of differential inhibition expected from the monosyllables in a normal processor.

7.7. Methodology

The experiments described in the current and following chapter employed a Gating Paradigm as the tool to investigate processing of overlapping lexical hypotheses.

7.7.1. Requirements of the current hypotheses.

The objective of the two experiments was similar: to discover which type of word candidates are entertained transiently in word recognition when overlapping lexical hypotheses are presented by the speech stream. This requires a means of recording processing activity at the intermediate stages of recognition and a method of examining how this relates to the final performance. Specifically, the current investigations require a way of locating the point at which the first polysyllabic hypothesis is isolated by the listener. Further, it demands the possibility of accurately locating the point at which the target word is isolated, and recording which competing hypotheses reach sufficient activation levels to be proposed as alternatives to the target.

7.7.2. Constraints imposed by other factors

A propensity to lability and a typical attenuation of performance when cognitive load is too high, are commonly reported features of aphasic performance. Thus it is desirable to avoid rapid response requirements. Reaction time experiments, which demand quick responses, can be cognitively demanding and stress inducing, and so are generally unsuitable for this subject population. If reaction times are recorded from aphasic subjects, one needs to employ a metric to compensate for any delays due to physical slowness rather than latency of recognition. It is not clear, however, how this equation should be structured. If an on-line investigation is required, then one which does not place such an emphasis on rapidity of response is needed. Gating provides such a paradigm.

7.7.3. The Gating Paradigm

The gating paradigm was first elaborated by Grosjean in his paper "Spoken word recognition processes and the gating paradigm" (1980) and has become established as a standard method of investigating real time (on-line) speech recognition processes. It is, however, still somewhat controversial. Gating is an on-line paradigm which reveals the temporal location of word recognition and the nature of the lexical items which are partially activated as a function of the sensory and contextual information present. Gating studies can yield qualitative as well as quantitative data: this is their strength. They show which candidates are partially primed *en route* and which variables affect the level of activation of hypotheses and earliness of recognition, not simply which words are recognised quickest.

7.7.4. Data analyses

The data gleaned from gating tasks are rich and various. The type of data found are of two sorts; identification results and error data. The identification results include the point at which the independent variables have the anticipated end effect. This may be in the form of, for instance, isolation point, recognition point, or poly-point (the point at which hypotheses change from monosyllabic to polysyllabic ones). Error data include erroneous confidence ratings, or guesses involving competitor candidates. Depending on the structure of the stimuli, this may illuminate the sequence and extent of garden pathing (maintenance of an erroneous guess over successive gates). Among the most robust garden path effects are the frequency garden path and the "word from a word" path. The first entails the maintenance of the most frequent competitor of the established cohort as the hypothesis; for instance if the target is **TRAWLER** competitors such as **TRAIN** and **TRUCK** are guessed over successive gates. "Word from a word" garden paths involve proposing words embedded within the target word as hypotheses, for example when the target is **FACTORY** but candidates such as **FACT** are guessed for several gates. Error data is of particular use when the target word is not identified even at offset of the word. This is often the case with aphasic subjects. Error analysis can indicate whether this was possibly due to the correct hypothesis not being entertained, or being entertained among too many, too powerful competitors. It shows at which point garden path candidates emerge and the extent of their influence and can also illustrate any unusual relationship between the isolation and recognition points.

7.7.5. Description, Definition and Terminology

Gating entails presentation of the target stimuli in fragments which increase in length with each successive pass. Forward gating involves editing the target a specified length of time after the stimulus onset, and successively playing out the stimuli augmented in increments (gates) of this same length. This allows examination of how much of a given stimulus the subject requires to perform the task under observation and allows an estimation of the point at which perception can be completed successfully in more normal circumstances.

The nature of the investigation constrains the span of the material to be gated: Material may be gated over a word-, phrase- or sentence-length portions. Similarly, the hypothesis being tested dictates whether the gates are time-specified (typically in 50 millisecond chunks) or segment-specified portions (after phoneme-, syllable- or word-level segments).

For example, gates constructed at multiples of 50 millisecond intervals would result in something which could be represented as follow:

Gate 1	50ms	c.........
Gate 2	100ms	ca........
Gate 3	150ms	cart......
Gate 4	200ms	cartr.....
Gate 5	250ms	cartri....
Gate 6	300ms	cartridge

In this respect gating is different from on-line paradigms such as reaction time, naming or recognition tasks, which only indicate which features of language facilitate or inhibit processing, but do not necessarily give such a direct insight into the state of processing and the amount of recognition achieved after the perception of precisely measured portions of sensory input. Word gating experiments measure the effect of a given independent variable on the isolation point (IP) or poly-point (PP) of target materials. The IP is defined as the moment when the target word is first successfully identified by the listener in two successive selections without returning to any alternative candidate at a later stage. The IP reflects the fact that sufficient sensory information has arrived for the target candidate to be isolated from all other competitors. The poly-point is the point at which, in polysyllabic stimuli, the listener first adopts polysyllabic hypotheses.

7.7.6. Materials preparation requirements

The splicing and waveform editing entailed in gating material preparation is a laborious task and subsequently many investigators employ automatic or computer directed programmes to create their stimuli. In time-level gating it is of prime importance that gates are of uniform and precisely measured length. Splicing a speech stream at a point strictly specified in terms of time from word onset, however, may create stimuli which are truncated when the wave amplitude is high. The sudden drop down to zero amplitude (which it is bound to do as silence which has zero amplitude necessarily follows the gate) yields a perceptual click. This potentially biases listeners toward identifying stimuli as plosives which are characterised by sudden change from zero to high amplitude waveform movements. The early gating experiments make no mention of whether they have compensated for this, but a recent convention has been to cut the stimuli at a zero crossing within +/- 5mscs of the optimum splice point, or to smooth down (often referred to as ramping or hammocking) the stimulus offset gradually to zero from +/- 5mscs of the optimum offset. Both eliminate the sudden amplitude shift and remove auditory clicks from the materials.

7.7.7. Critique of paradigm

Much of the criticism of the paradigm results from the perceived artificiality of the presentation format or the distance between it and overt behaviour in natural perception. The repeated presentation of essentially the same stimuli is undeniably dissimilar to everyday perception requirements. This is not *a priori* problematic. What is crucial, however, is to decide whether this artificiality is sufficiently unnatural to disrupt the natural process system or induce the use of compensatory or alternative processes. Specifically, the two most substantial misgivings about the methodology are concerns about whether the format and response mechanisms capture real time functioning and whether the presentation forces the occurrence of something other than the regular sequential analysis of speech stimuli found in natural speech perception.

The original gating experiment (Grosjean, 1980) was validated by comparing its findings with those of established Reaction Time techniques. To prove that the gating paradigm could illustrate the effects of language phenomena, Grosjean compared the qualitative results against those from other methodologies. The qualitative effects of frequency, context and word-length on word recognition were found to be equally well captured by the gating technique as by more conventional reaction time methods.

7.7.8. Does successive presentation elicit non-natural recognition patterns?

The first misgiving concerns the repetitious nature of stimulus presentation. Repeated exposure to the stimuli could potentially alter the isolation point as well as any confidence rating. It has been argued that, knowing that they are going to hear more and more of the target word, subjects rate confidence in a steadily increasing manner rather than in a way which reflects underlying assurity of identification - something which may be more erratic. Repeated information may also help home in on the intended candidate more quickly than is normal. Cotton and Grosjean (1984) investigated this by adapting the gating paradigm such that each gate of a word was heard by a different subject. Data from the individual presentation format was compared with that from the successive play technique to evaluate how much of the isolation point detail and confidence ratings were a function of the paradigm rather than underlying processes. They found "*that the same amount (sic) of subjects guessed the words correctly at each test gate in each context condition and this number increased as subjects heard more of the word*". Isolation point, therefore, does not seem to be an artifact of the paradigm. Error analysis shows that the gating presentation format does not influence the type or sustenance of garden paths whether they are of the "word within word" type or "frequency" type. Thus, gating would appear well suited to investigate typical candidate activation.

7.7.9. Does gating reflect real-time processing?

Let us next consider the objection that gating is not a real-time analysis of speech processing. Responses in gating experiments are not typically timed; the investigator has no record of how quickly a subject responds. The subject potentially has time to consciously evaluate their guesses. This opportunity for metalinguistic reflection, and the possibility that this yields responses which do not represent candidate superiority in real-time processing, is the second factor which engenders criticism of the technique.

Tyler (Tyler, 1985) addressed this question in a timed naming gating-task. Subjects were instructed to name the word they thought they were hearing as quickly as possible; results were compared with those of a comparative non-timed gating task (Tyler &

Wessels, 1983) and conventional reaction time tasks (Marslen-Wilson & Welsh, 1984, Ottevangr, 1983). Naming latencies across all three paradigms were comparable and suggest that the same underlying processes are being captured. Timed gating does appear to be revealing on-line processes, but do the non-timed gating tasks that are generally used capture the same information as the timed gating tasks reported by Tyler and Wessels?

To investigate this second point, the timed responses were analysed against non-timed counterparts (Tyler, 1985). They showed strikingly similar patterns of lexical candidate selection, earliness of selection, and effects of context: both versions are apparently tapping into the same processes. These findings suggest that the delay and potential for metalinguistic reflection do not alter the sequence or nature of the process. Furthermore it would seem that they reflect analogous information to that revealed by reaction time studies. These comparisons, however, should be treated with some caution as the non-timed data used came from *inter alia* lexical decision tasks. Naming and lexical decision are known to require differing processing capacities so the reaction times from each study are not necessarily comparable.

One further point in defence of the validity of gating made by Tyler (1992) is that giving a spoken response may not necessarily entail conscious behaviour by the subject (see Marslen-Wilson's assessment of subjects in shadowing tasks where response is not considered to be *a priori* consciously directed). The guesses given may be much more transparently close to the unconscious emergence of candidate word hypotheses than is often argued.

It would seem therefore, that the earliest moments of processing are captured relatively accurately by gating and are least susceptible to influence of conscious reflection. Conscious searching of the lexicon does not help a lexical candidate emerge as a competitor for identification, but when there is a context to help, conscious metalinguistic consideration of candidates may influence the final decision to identify one word over all its competitors.

7.7.10. Gating with older subjects

Experiments 4 and 5 directly compare data from gating experiments in which both the aphasic and the normal control subjects are ageing. Given that the aphasic and normal subjects are substantially older than the young samples used in much of the previously reported gating literature, it is important to assess the validity of using the task on such populations and comparing resultant data with that of younger subjects. The literature shows (Elliot et al, 1987, Craig, 1992) that older adults isolate target candidates later than younger subjects. On average it took older adults 50ms longer than teenagers, to reach the highest confidence ratings, thereby causing their recognition points to be recorded as significantly later than those of children or young adults (Elliot et al, 1987). Craig notes that because of this later isolation, confidence ratings at isolation tend to be higher than those recorded for young subjects. Such factors must be considered in analysis of the collected data.

7.7.11. Gating with pathological groups

The work to date with aphasic subjects has tried to illuminate differences in subjects' abilities to construct intermediate representations of percepts using on-line tasks (Tyler, 1992). Hypotheses that some aphasic language deficits, although observable at the final stage of processing were not as evident as processing occurred, were tested using the gating technique (Tyler et al., 1990). The aim of the investigation was to locate the processing deficit of a non-fluent subject. Off-line tasks showed the patient to have below normal performance in processing syntactically complicated language. Using a 50msc gating task, Tyler tested the subject's ability to identify derivational and inflectional morphologically complex suffixed words. Results were within the normal range, which implied that the subject had no problem mapping sensory information onto representations of phonological form (Tyler et al., 1990).

Note that in this instance only isolation points were recorded as it was felt that confidence ratings could not be collected. This was not an *a priori* limitation for all gating with aphasics but dependent on the abilities of the individual subject. It would not necessarily be a restriction imposed by all aphasics.

A recent body of work has further enhanced the reputation of the use of this paradigm with the disordered speech community (Tyler, 1992). Subjects with mild, moderate, and severe aphasias, presenting with "anomic" "nonfluent" "fluent" and "global" patterns of impairment have been fruitfully tested using gating. Numerous combinations of performance abilities have been uncovered with regards processing of morphologically complex and simple words on this on-line task and results were compared with those from off-line experiments. Significant differences were reported in on- and off-line performances and insights into relative functioning of transient and final stages of access to representations were obtained. The fluent subject analysed in this series proved to have impaired performance on the off-line tasks testing his lexical decision responses to the the test items, while his pattern of intermediate representations (tested using gating) was within the normal range. The interpretation given is that his problem is in maintaining stable access to the final representation of the successfully selected word hypothesis. The gating data showed that mid-processing he accesses suitable competitors to a sufficient degree of activation for potential recognition, although he fails to sustain activation of the target candidate long enough for successful lexical retrieval.

7.7.12. Gating techniques used in the present thesis.

The gating technique employed here in both gating paradigm investigations used an isolated word, forward, 30msc gate successive presentation format[5]. That is, the gates were multiples of 30ms long, each fragment was measured from word onset and each subject first heard the initial 30ms of the target word, then the first 60ms and so on, in successive presentation, until the full word was heard.

Target items were presented without any prior context. Context-free presentation was chosen for a number of reasons. The first was to eliminate noise from the collected data; misinterpretation of the context might lead to variation in the dependent variable which was not due to the effect of the independent variables (frequency of the monosyllable and polysyllable competitors). The nature of embedded words and their relation to their carrier words also had a bearing on the presentation format. Embedded words share a

[5]A pilot study with A.L. used 50msc gates. His performance was of a standard which suggested he would be capable of undertaking the more time consuming, more demanding but more illuminating 30ms gating task.

majority of their carrier words initial syllable acoustic-phonetic information; the carrier word has further acoustic information, its second syllable. Context prior to a target item can give crucial prosodic information as to the length of the sentence (Grosjean, 1983). When the investigative task requires estimation of whether the word heard is mono- or polysyllabic, uncontrolled (and uncontrollable) prosodic information in context sentences would confound the effect of the measured variables of frequency or word class. It is therefore more suitable to test the phenomena using isolated word tokens.

7.7.13. Design

A 2 x 2 design was used: Monosyllable type (2 levels; frequent, rare) x Polysyllable type (2 levels; frequent, rare). Materials were crossed to generate four cells (Frequent Polysyllables with frequent monosyllable pairs; Frequent Polysyllables with rare monosyllables pairs; Rare Polysyllables with frequent monosyllable; and Rare Polysyllables with rare monosyllables. Each cell contained 8 pairs of stimuli (e.g. FPfm contains 8 pairs of words of the sort *began* and *big*). A latin square design was used to generate two listening conditions. Subjects in each listening conditions heard only one member of each pair (e.g. Listening Condition 1 subjects heard *began*, in Listening Condition 2 subjects heard *big*). Normal subjects were matched across listening conditions. The aphasic subject heard all tokens with a period of one month between presentation of each listening condition. A set of two practice items, containing an example of a monosyllable and a polysyllable word was also constructed. The same practice sets were spliced onto the start of each experimental tape. Experimental materials are listed in Appendix D.

Materials consisted of 32 polysyllables each of which were paired with 32 independent monosyllabic words. The monosyllabic words also comprised the first syllable of the polysyllabic word (e.g. pure/puerile). All rare materials had a frequency count of 31/500[6]. Frequent polysyllables were the most frequent polysyllabic word in their cohort. At the offset of the competing monosyllabic word, the cohort contained no more frequent competitor than the monosyllable used. Rare polysyllables are not necessarily the rarest in their cohort, but at the offset of the competing monosyllable, the cohort contained no more frequent competitor than the monosyllabic word used.

[6]These counts refer to number of 2000 word text samples in which this item features in the lexical analysis provided by Francis & Kucera (1982).

Table 7-3: Experiment 4; Example of Materials in each treatment

Example Cells for Gated Embedded Word Detection Experiment 4			
FREQUENT POLYS FREQUENT MONOSYLLABLE	*FREQUENT POLYS RARE MONOSYLLABLE*	*RARE POLY FREQUENT MONOSYLLABLES*	*RARE POLYS RARE MONOSYLLABLE*
began/big	curious/cure	puerile/pure	jigsaw/jig

7.7.14. Preparation of materials

Materials for Experiment 4 were selected from a set prepared by Ellen Bard, Richard Shillcock and Cathy Sotillo and were used in this study with their permission. Preparation of materials followed the stipulations cited above in section 7.7.6. Materials were recorded by an English male speaker in list form then spliced from the top then the bottom of the list; editing was achieved using a Xerox D computer.

Two lists, corresponding to two conditions, were constructed each containing equivalent numbers of polysyllabic and monosyllabic words from each frequency cell. Word order was randomised and was consistent across both listening conditions. Where the polysyllabic word from one cell occurred in list A (e.g. *"puerile"*), its monosyllabic mate occurred in list B (e.g. *"pure"*), and vice versa. Two practice items were presented before each experimental session.

7.7.15. Subjects

The performance of a fluent aphasic was compared to that of a group of normally ageing native English speakers. The control population consisted of a set of 8 young ageing (50-60 years old) and (60+) elderly subjects who matched the aphasic subject in educational and socio-economic levels. None of the control subjects had any hearing, cognitive or linguistic impairments.

7.7.15.1. Aphasic Subject Profile

The aphasic subject, A.L., was born in 1931 and suffered a vasospasm on 16.9.90 following the excision of a supre-sella meningioma on 11.9.90. He had no previous history of linguistic or cerebral impairment. His speech immediately following the vasospasm consisted mainly of stereotyped utterances such as "I haven't the faintest", and "The only snag is...". He was initially diagnosed as having a severe mixed aphasia. He received speech therapy both as an in-patient and latterly as an out-patient until September 1991. Since this time he has taken part in a selection of research projects.

His later output suggests he has a mild to moderate aphasia. His general comprehension is good though detailed lexical access and auditory perception are below normal levels. Prior to the vasospasm he worked as a building surveyor for a brewery and had reached a senior position. His motivation is high and he eagerly accepted the invitation to take part in any research that might throw light on his condition or stretch his language perception capacities.

On a battery of cognitive neuropsychologically motivated assessments[7], A. L.'s performance confirmed the diagnosis that he showed a mild to moderate degree of impairment. The profiling test scores were as follows:

Table 7-4: Profiling Test Scores

PALPA-TYPE PROFILING BATTERY RESULTS	
Non-Word Auditory Discrimination	85%
Real Word Auditory Discrimination	90%
Word-Picture Matching	83%
Auditory Lexical Decision	88%
Visual Lexical Decision	91%
Synonym Matching	94%
Word initial Phoneme identification	71%

[7]Based on PALPA (Kay et al., 1988) and tests supplied by Sue Franklin.

7.7.15.2. Motivations for subject choice

There was both a theoretical and practical impetus for the use of this aphasic subject. Theoretically, it was felt that a single case study would provide the most illuminating data for this task. Gating allows the collection of many exemplars of one subject's responses which provides the opportunity for analysis of data using powerful statistics. It is, however, demanding and beyond the capacity of many subjects. It was felt that more could be learned from an in depth study of the on-line analysis of one subject than from data of questionable validity from subjects whose performance was hindered by physical rather than linguistic or cognitive deficits. Thus a single case study analysis was thought most appropriate.

This subject's linguistic profile is one which suggests that at the lexical and phonological levels he is only mildly below normal, but conversationally he is unable to follow normal speed speech with normal efficiency. This pattern of being efficient at tasks where full concentration could be directed to a discrete task (like the profiling tests) and lesser efficiency in more demanding tasks (like conversation) suggested a degradation across the processing system as a whole rather than a deficit attributable to an individual linguistic module. On a practical level, gating is a notoriously strenuous paradigm which requires well motivated, stable participants whose concentration can be maintained for an extended period of time. A. L. displayed such characteristics.

7.7.16. Procedure.

All stimuli were presented using a 30msec forward gating paradigm which closely follows the description given above. After presentation of each fragment the listener is asked to guess the identity of the whole token. All stimuli were presented aurally over headphones from a digital audio tape player. Control subjects were tested individually in one session in a quiet room. An accommodation tape on which the speaker read a passage was played at the beginning of each listener session to familiarise the listener with the speaker's voice. A set of 2 practice items was played before the task proper began. Subjects were encouraged to make a response at each gate.

The aphasic subject was introduced to the experimental paradigm during the pilot study. The methodology was demonstrated using a series of visual and verbal aids. The subject was shown a partially covered picture of a familiar object and asked to identify it as it was revealed piece by piece. Then the experimenter spoke the subject's name in successively longer fragments, asking for guesses as to what was being said. Finally the experimenter uttered increasingly long fragments of a series of familiar words which contained words embedded within and asked the subject to give guesses as to the utterance's identity after each fragment. When the experimenter was satisfied that the subject was at ease with the nature of the task, practice with taped materials ensued. A taped passage read by the speaker was played over the headphones to familiarise the subject with the speaker's voice and establish an optimum listening level (amplitude/volume). The subject was instructed to listen to a set of practice items and give a guess at each gate. The subject was encouraged to guess even if he was unsure of the word and were advised that it would not be unusual for non-impaired listeners to give erroneous guesses early in the word and that selection of different hypotheses at a later stage was also common practice.

All responses during the test proper were recorded onto an answer sheet by the experimenter; part words or nonsense items were written in phonetic script. Successive repetition of response was recorded using a ditto mark.

7.7.16.1. Motivation for use of on-line investigative technique

The hypothesis under investigation here is that for normal subjects the frequency characteristics of lexical hypotheses will affect the activation and competition of competing candidates and will thereby cause differential emergence patterns of target hypotheses. My focus is not on the speed with which the targets are eventually recognised but rather on investigating the earlier, 'intermediate' (Tyler, 1992) stages of processing. It is proposed that these representations give a more direct insight into the decision for lexical access and segmentation of the speech stream when strings contain overlapping hypotheses. It is more parsimonious then to use a paradigm which allows analysis of hypotheses as they emerge rather than consideration of post recognition performances which require extrapolation from reaction time of error rate data for recognition points back to isolation points. This is a risky strategy as it is not clear whether there is a constant linear relationship between the recognition point and isolation point.

Insight into first pass automatic processes can most effectively be gained by using an experimental technique which taps directly into early stages of language processing. Looking at first-pass processes is especially instructive when enquiring into aphasic processing as it allows us to avoid interference from compensatory or conscious processing strategies for which linguistically impaired subjects are notorious. Gating is claimed to be an on-line paradigm.

When investigating pathological processing on-line paradigms offer a further advantage: collection of on-line data makes it feasible to compare between early and late processing strategies as revealed in intermediate and end-point data (reflected in this investigation in responses to early and late gates). Recent on-line investigation with aphasic subjects (Tyler, 1992) has revealed that they display many different relative on- and off-line patterns of performance. In some cases the aphasics off-line task scores seem to indicate that they are qualitatively different from normal, while an on-line measure on the same task suggests that at earlier 'intermediate' stages in processing, the difference is more accurately described as quantitative. Tyler (1992) examined the abilities of normal and aphasic listeners to construct intermediate representations of morphologically complex words. Her results showed that the aphasics often behaved differently in their construction of intermediate and final word forms. Such information allows a more accurate understanding of the nature of the subject's deficit. Furthermore, it allows us to estimate the interaction of a variety of lexical features, to gauge their effect on ultimate word recognition as well as their mid-processing inhibition of competitor candidates.

On-line studies enrich our knowledge of aphasics' abilities with a more detailed picture of their processing *during* the recognition of speech. It is potentially useful in contributing knowledge to fields where results are frequently contradictory. It allows clearer more accurate diagnoses of patients and better generalisations. In a broader sense, it has been claimed (Prather et al., 1991) that on-line investigation gives a more detailed picture of processing and is therefore an invaluable too for deficit and lesion localisation.

7.8. Results

The experiment provided data for a series of analyses. The first set of analyses considered responses made by normal ageing adults to the materials where the target was polysyllabic. Of these, the initial analysis was concerned with the point at which the listener first gave a polysyllabic response to the stimulus. Such a measurement would illustrate the relative power of the monosyllabic competitors to delay the adoption of strong polysyllabic contenders (i.e frequent polysyllables) for lexical identification.

The gate at which the listener first gave a polysyllabic response was labelled the "poly-point". This was measured against the objective point at which acoustic information signaling that the stimulus is not monosyllabic, is present[8]. This second measure is referred to as the "divergence point". To compare, across materials, the effect of monosyllabic and polysyllabic frequency ratings on polysyllable guessing, the following computation was carried out:

Poly-lag = DP - PP

DP = divergence point
PP = poly-point
PL = poly-lag: the delay of polysyllabic hypothesis adoption relative to the point of divergence.

The poly-lag of each word for each subject was thus computed and compared across cells and between groups.

7.8.1. Difference between normal and aphasic performance

A by-materials *t-test* was computed to ascertain whether the aphasic subject's performance was sufficiently different to that of the mean performance of the control group to suggest that he was from an independent category. The *t-test* upheld the one-tailed hypothesis that the aphasic poly-lags would be longer than those of the normal subjects (t = -1.71, *df* (28): $p < 0.05$.) A trimmed *t-test*[9] which removed 2 outliers and, revealed a more striking difference between the groups' performance (t = -3.13, *df* (26) p

[8]The objective point was found by listening to each gate and examining the waveform for clear indications that the word did not end with the first syllable: knowing what the polysyllable was we could have put this point as early as we heard co-articulation, but instead we were conservative: we chose as divergence point that gate which contained the first material that could not have belonged to the monosyllable.

[9]The statistical package dictates the removal of outlying data points.

< 0.005) The normal subjects consistently suggested polysyllabic candidates at earlier gates than did the aphasic.

7.8.2. Normal ageing poly-lag performance

For the normal subjects the effect of the monosyllable and polysyllable frequency on emergence of polysyllable candidates was measured using a two-way ANOVA. The effect of monosyllable frequency was significant ($F_1(1, 28) = 10.61, p < 0.003; F_2\ (1, 25) = 9.51\ p < 0.01$; MinF'(1, 52) = 5.01497, $p < 0.05$). That is, the frequent monosyllables delayed the adoption of polysyllabic competitors significantly longer than did the rare monosyllables. Neither the effect of the polysyllable frequency: ($F_1(1, 28) = 2.80, p = 0.11; F_2\ (1, 25) = 1.59, p = 0.2$) nor the interaction of polysyllable frequency and monosyllable frequency ($F_1\ (1, 28) = 2.46, p = 0.13; F_2\ (1, 25) = 0.45, p= 0.5$) was significant. (See Figure 7-1). The lack of interaction in this data would seem to support the notion that there is no lateral inhibition operating.

7.8.3. Aphasic poly-lag variation

When the poly-lag data for the aphasic listener were analysed using a two-way ANOVA, no significant effects were found. The by-materials analysis yielded the following results: the effect of monosyllable frequency ($F(1, 25)= 0.66, p = 0.42$) the effect of polysyllable frequency ($F(1, 25) =0.0, p = 0.96$) and the interaction ($F(1, 25) = 1.79, p < 0.19$) all failed to reach significance. (See Figure 7-2). The raw mean poly-lags for the four cells shows that the poly-lag for the Rare polysyllable with frequent monosyllable competitor materials (*pure/puerile*) is substantially longer than for materials in the other cells, indicating that the adoption of a polysyllabic guess is much delayed when the monosyllable competitor is frequent and the target polysyllable is rare. The large standard deviation of this mean accounts for it not reaching significance in the ANOVA. The fact that the biggest delay occurs in the Rare polysyllable with frequent monosyllable competitor cell is in the direction predicted by a model without lateral inhibition.

Figure 7-1: Adoption of polysyllable lexical hypotheses by Normal Subjects

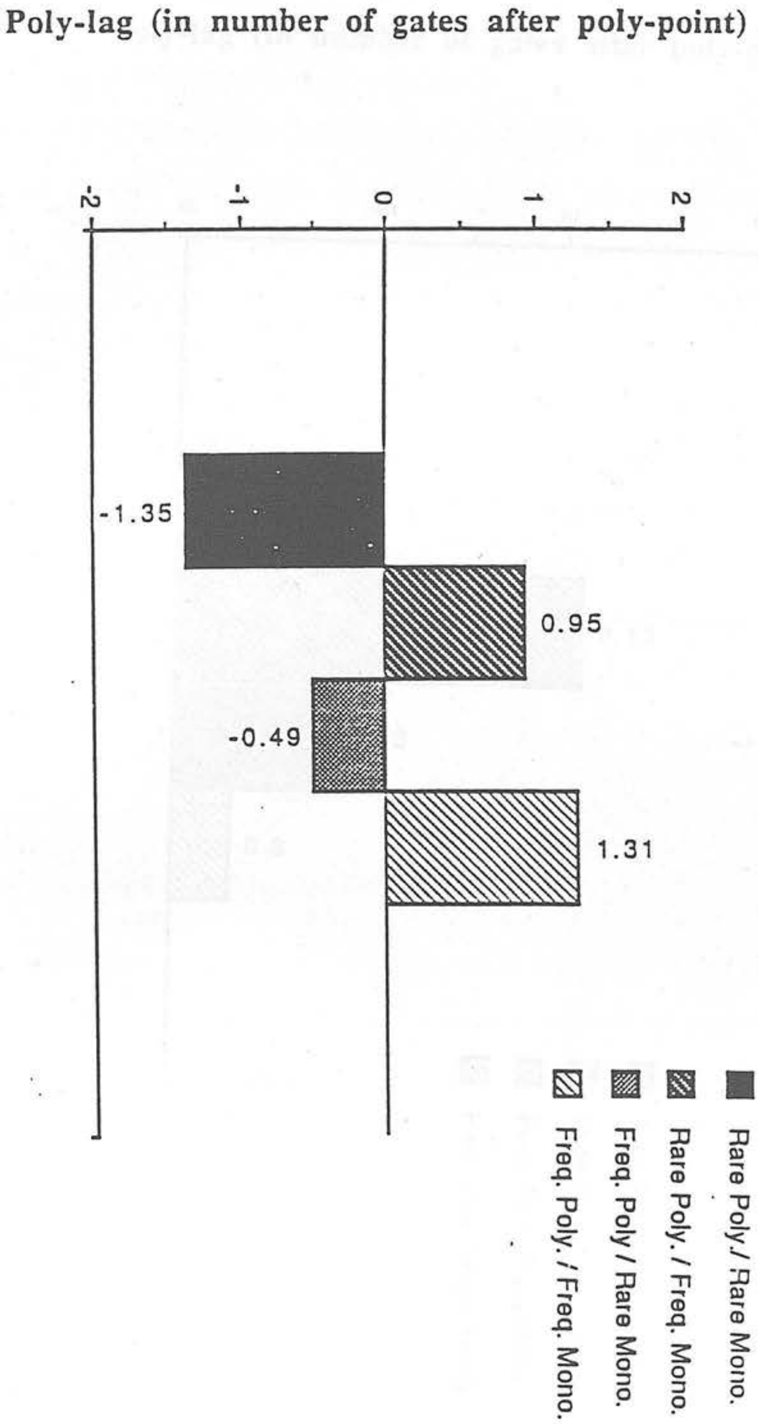
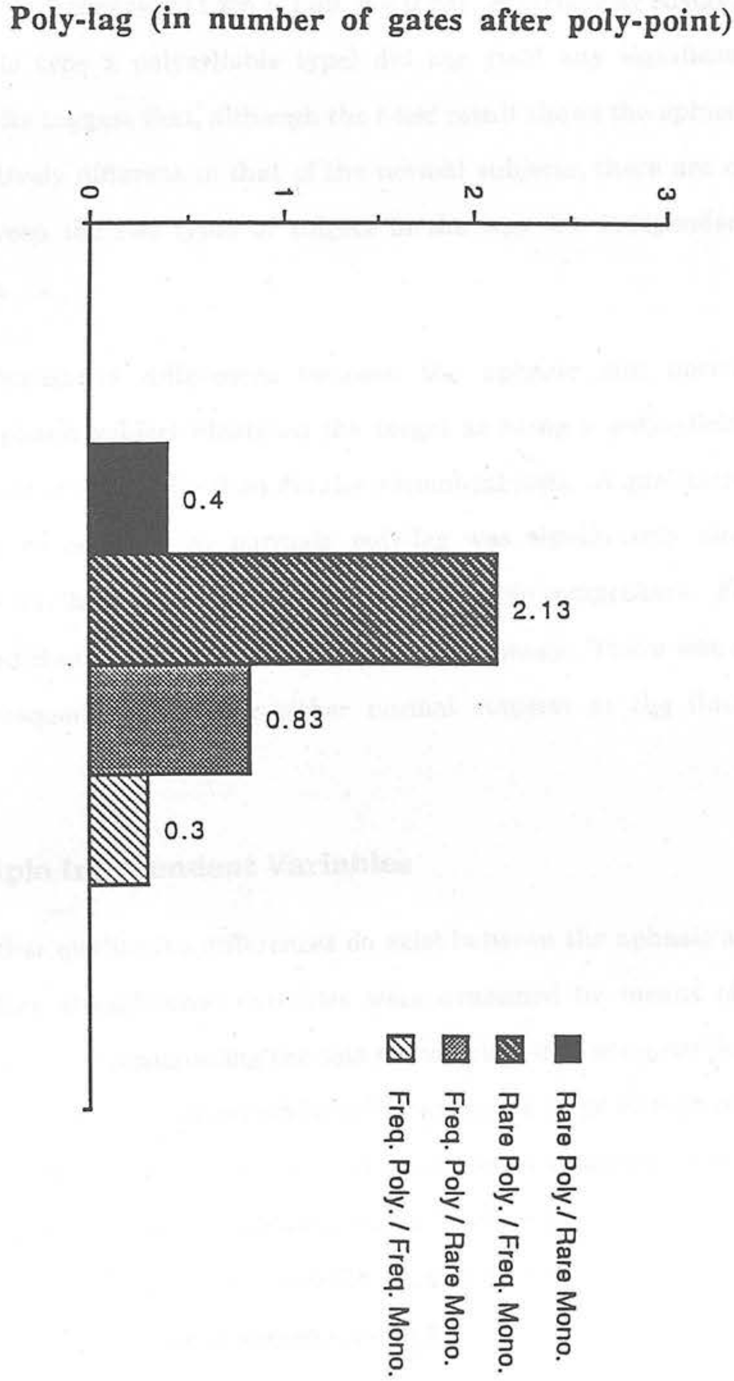


Figure 7-2: Adoption of polysyllable lexical hypotheses by a Fluent Aphasic Subject



7.8.4. Difference between the aphasic and normal performances

The difference between the aphasic and control performance poly-lag for each material was examined with respect of the independent variables of monosyllable and polysyllable frequency. The frequency of the monosyllable did not cause the normal poly-lags to be shorter than those of the aphasic, ($F(1,25) = 2.93$, $p = 0.09$), nor did the frequency of the polysyllable (F (1, 25) = 3.55, $p = 0.07$) nor did the interaction of the monosyllable and polysyllable frequency ($F(1,25) = 1.39$, $p = 0.25$). A three-way ANOVA (subject type x monosyllable type x polysyllable type) did not yield any significant results. These ANOVA results suggest that, although the *t-test* result shows the aphasic performance to be quantitatively different to that of the normal subjects, there are no qualitative differences between the two types of subject in the way the independent variables affect poly-lag size.

In sum, there were quantitative differences between the aphasic and normal performances in that the aphasic subject identified the target as being a polysyllable longer after the objective point of syllabicity than did the normal subjects. A qualitative difference also appeared to be evident: the normals' poly-lag was significantly more delayed by the frequent monosyllables than by the rare monosyllable competitors. For A.L. this delay was not predicted simply by the monosyllable frequency. There was no evidence for polysyllabic frequency effects for either normal subjects or the fluent aphasic.

7.8.5. Analysis of Multiple Independent Variables

In order to see if any further qualitative differences do exist between the aphasic and normal processing, the effect of additional variables were examined by means of a multiple regression analysis.[10]. In constructing the sets of materials it is not possible to balance all possible sources of variance *a priori* while still producing a large enough data set to give reliable results. Thus factors relating to the number of competitors, total frequency of the competitors and identity of the most frequent competitor in the cohort could not be fully balanced out across cells. It is possible that such factors are obscuring differences in processing between the normal subjects and A.L.

[10]See Chapter 4 for description and rationale of multiple regression analysis.

Table 7-5: Experiment 5 Key to independent and dependent variables

Variable number	*Description of variable*
1	Poly-lag data for normal subjects
2	Poly-lag data for aphasic subject
3	Frequency of the embedded monosyllabic word
4	Number of words in the cohort
5	Number of monosyllabic words in the cohort
6	Cumulative frequency of the monosyllabic words
7	Syllabicity of the cohort leader (i.e. monosyllable or polysyllable)
8	Frequency of the target polysyllabic word
9	Difference between the frequencies of: - The embedded monosyllabic word and the cohort's highest polysyllabic word.
10	- The cohort's highest monosyllabic word and its highest polysyllabic word.
11	- The embedded monosyllabic word and the target polysyllabic word.
12	- The cohort's highest monosyllabic word and the target polysyllabic word.
13	The most frequent polysyllabic word in the cohort
14	The number of polysyllables in the cohort.

7.8.6. Data from analysis of Normal subjects' responses

7.8.6.1. Hierarchy 1

Monosyllable frequency is correlated with poly-lag in a simple correlation (r = .32 (113), $p < 0.0004$). There is a significant increase in the account of variance when the cumulative frequency of the monosyllables is entered into the equation and partialled out with monosyllable frequency and number of monosyllables (R^2 = .20, $F(3, 111)$ = 9.33, $p < 0.0001$). All three variables seem to contribute independently to the account of variance (monosyllable frequency, β = -.58, $p < 0.03$; number of monoysllables, β = -.35, $p < 0.04$; and cumulative frequency of the monosyllables, β = 1.20, $p < 0.00$). There were

Table 7-6: Hierarchies used in the Multiple Regression Analysis of the normal and aphasic poly-lag variance

Hierarchy	*Variables in order of entry*
Hierarchy 1	Monosyllable frequency, number of monosyllables, cumulative frequency of the monosyllables, syllabicity of cohort leader (monosyllable or polysyllable), target polysyllable frequency, number of polysyllables.
Hierarchy 2	Monosyllable frequency, cumulative frequency of the monosyllables, cohort size, target polysyllable frequency.
Hierarchy 3	Monosyllable frequency, number of monosyllables, cumulative frequency of the monosyllables, syllabicity of cohort leader (monosyllable or polysyllable), highest polysyllable frequency, number of polysyllables.

no further significant increases in the amount of variance accounted for. When all variables are partialled out, the total amount of variance accounted for is 23% ($R^2 = .23$, $F(6, 108) = 5.302$, $p < 0.0001$). The monosyllable frequency variable retains its unique contribution to the account of the variance ($\beta = -.72$, $p < 0.02$). Number of monoysllables is also shown to be making an independent contribution to the account of variance in poly-lag ($\beta = -.40$, $p < 0.02$) as does cumulative frequency of the monosyllables ($\beta = 1.22$, $p < 0.00$). Although the addition of the target polysyllable frequency and number of polysyllables in the cohort variables to the equation did not significantly increase the account of variance, their inclusion has raised the β values of the three monosyllable variables. This suggests that they are interacting with the monosyllable variables

7.8.6.2. Hierarchy 2

A similar hierarchy in which number of monosyllables, was replaced by cohort size gave a lesser account of the variance at 17% ($R^2 = .17$, $F(5, 109) = 5.64$, $p < 0.0004$). This adds weight to the assumption that competitors from the whole cohort are not acting with equal strength at the point of adoption of polysyllabic hypotheses.

7.8.6.3. Hierarchy 3

The replacement of target polysyllable frequency by the highest polysyllable frequency made no alteration to the normal results.

7.8.7. Data from analysis of the aphasic subject's responses

7.8.7.1. Hierarchy 3

The addition of the number of monosyllables variable led to an increase in the amount of variance accounted for (R^2 (.05),$F(2,27) = .08$, $p < 0.1$). Of the independent variables partialled out in this equation, only the monosyllable frequency variable approached significance ($\beta = -1.24$, $p < 0.07$). When a further variable, the frequency of the highest frequency polysyllable in the cohort, a further significant increase in account of the variance occurs and the independent contribution made to this account by the monosyllable frequency variable is significant ($\beta = -1.53$, $p < 0.05$). That is, there is an association between an increase in the monosyllable frequency and the delay in adoption of poly-lag.

When all of the variables were partialled out (monosyllable frequency, number of monosyllables, cohort leader syllable count, cumulative frequency of the monosyllables, highest polysyllable frequency in the cohort and number of polysyllables in the cohort) the total amount of variance accounted for is 18% ($R^2 = .18$ $F(6, 23) = 0.8$, $p > 1$).

7.8.7.2. Hierarchy 1

When the the frequency of the highest frequency polysyllable in the cohort is replaced by the *the frequency of the target polysyllable*, the unique contribution made by the the monosyllable frequency only approaches significance ($\beta = -1.23$, $p < 0.08$). The total amount of variance accounted for by this hierarchy is lower than when the *the frequency of the highest frequency polysyllable in the cohort* variable is partialled out ($R^2 = .15$, $F(6, 23) = 0.7$, $p > 1$).

7.8.7.3. Hierarchy 2

Partialling out cohort size as a single variable (rather than partialling out number of monosyllables and number of polysyllables as independent variables) does not produce an account of the variance which allows the emergence of any unique contributions from other variables. The total account of variance is also very low at 7% when all of the variables in the hierarchy are partialled out (($R^2 = .07, F(4, 25) = 0.5, p > 1$).

7.8.7.4. Summary

These results show that a monosyllable frequency effect does emerge for the aphasic subject when the number of monosyllables has been balanced out. The effect of monosyllable frequency for the normal subjects which was initially shown in the ANOVA results, is still apparent from the Multiple Regression Analyses. The regression coefficients suggest that the number of monosyllables and the cumulative frequency of the monosyllables also make a significant unique contribution to the variance in the normal poly-lag variance. The polysyllable features make no significant contribution to accounting for any variance in either the aphasic or normal polysyllable data.

7.8.8. Commitment to the target polysyllabic candidate

I next tested the effect of the originally defined independent variables (polysyllable and monosyllable frequency) on the delay between initially offering a polysyllabic hypothesis and commitment to the target candidate. It was not possible to compute the uniqueness point for the materials so an alternative measurement of recognition was computed. This entailed measuring the length of time from the poly-point to the gate at which the correct target was elicited without the speaker later giving an alternative response.

For the normal subjects, there were no main effects for polysyllable frequency ($F(1,24) = 3.01, p = 0.09$); monosyllable frequency ($F(1,24) = 0.14, p = .7$); and no interactions ($F(1,25) = 0.01, p = 0.9$). That is, neither of the independent variables affected the delay between first hypothesising polysyllable candidates and commitment to the correct polysyllabic target.

For the aphasic subject, there was a significant main effect of monosyllable frequency ($F(1,24) = 4.31$, $p > 0.05$); but no effect of polysyllabic frequency ($F(1,24) = 0.07$, $p = 0.7$) nor any interaction ($F(1,24) = 0.01$, $p = 0.97$). The means indicate that the monosyllable effect is such that the rare monosyllable words cause less of a delay between posing of a polysyllable hypothesis and adoption of the target. There was no significant difference between the aphasic and normal performances with regards the independent variables: monosyllable frequency ($F(1,24) = 0.92$, $p = 0.3$), polysyllable frequency ($F(1,24) = 2.86$, $p = 0.1$), or interaction ($F(1,24) = 0.01$, $p = 0.9$).

A *t-test* shows that the aphasic has a consistently shorter delay than the normal subjects between poly-point and identification ($t = 2.74$, $d.f. = 27$, $p < 0.02$). This suggests that the aphasics ability to offer polysyllabic hypotheses in the first instance may be heavily reliant on the building up of strong representations which may then be quickly confirmed.

7.8.9. Elicited Cohorts

There were significant effects on the number of responses elicited by either the aphasic or normal listeners of the polysyllabic word frequencies or of the monosyllabic word frequencies.

Models which instantiate lateral inhibition as part of their competition mechanism support the prediction that cohort size is influential in lexical access latencies. For the purposes of this investigation I was interested to establish whether the number of competitors sharing word initial segments delayed the point at which a polysyllabic candidate can be elicited.

The normal subjects' poly-lag does not correlate directly with the size of the cohort: $F(1, 28) = 0.213$; $p < 1$. nor with the the number of polysyllables in the cohort $F(1,28) = 0.22$; $p< 1$; nor with the number of monosyllables in the cohort; $F(1,28) = 0.137$, $p < 1$.

7.9. Discussion

7.9.1. Normal data

The normal subjects showed sensitivity to the frequency of the embedded monosyllable in the emergence of polysyllabic hypotheses. When the main monosyllabic candidate was frequent, the listeners took longer to switch to polysyllabic candidates. The frequency of the polysyllabic target was not a significant variable. The Normal ageing subjects stuck with their initial monosyllabic hypothesis longer when the monosyllabic candidate was frequent than when it was rare. This result lends support to the notion that monosyllabic hypotheses are activated early in the processing of strings, and their level of activation is, in part, frequency dictated. Early accrued activation of initial hypotheses is instrumental in delaying the emergence of competing candidates.

For the normal and aphasic subjects, neither by materials or by subjects analyses showed a significant effect of polysyllable frequency. It was predicted that the polysyllabic competitor's frequency would exert some effect on the adoption of hypotheses. A mundane explanation for this could be the small sample size. Future research with a larger normal ageing population could establish the validity of the lack of polysyllable frequency. Recall that the frequent polysyllables were the most frequent polysyllable in their cohort. An inspection of the cohorts shows that of the 16 rare polysyllabic items, 5 of the rare polysyllables were the most frequent polysyllabic candidate at the offset of the monosyllabic competitor. So although the polysyllables were rare, they were the most frequent polysyllabic options which matched the sensory input. This may have obscured the difference between these cells and the two which contained frequent polysyllables.

A further possible explanation arises from the measures being used: poly-point and poly-lag. At the point where the acoustic information is commensurate with polysyllabicity the acoustic signal still has the potential to match numerous polysyllabic hypotheses. In no case is there only one polysyllable in the cohort at the point of departure from the monosyllabic guess.

I would argue, however, that these data show that at the early stages of lexical recognition, the monosyllable competitor features are most salient. The multiple regression analyses results would concur with this. Although number of monosyllable competitors contributed to the poly-lag variance, the total number of words in the cohort, was not such a good predictor. I would posit that the whole cohort is not activated to the same degree initially, and that it is only when acoustic input commensurate with polysyllabicity is received that the full cohort operates on equal terms. If the full array of polysyllabic features are not called into play until later, then one would not expect to see a pronounced polysyllable competitor frequency effect. This has implications for segmentation. The competition between late and early offsets would be weighted in favour of the early offset. This, of course reflects the partitioning of the lexicon[11] and would be a parsimonious feature to propose.

There was also a failure to find any interactions between polysyllable and monosyllable frequency on poly-lag. Recall that Bard (1990) predicted that if lateral inhibition were operating there would be an interaction between the longer and shorter hypotheses. The failure to find any interactions between the polysyllabic and monosyllabic hypotheses means that no support is found for the existence of lateral inhibition. If, however, the failure to find polysyllable effects alone is due to an uneven processing advantage for the monosyllable hypotheses, then the impact of the failure to find an interaction may be reduced.

7.9.2. Aphasic data

The Aphasic's offering of polysyllabic hypotheses was always delayed past the divergence point (the objective point at which acoustic information indicative of polysyllabicity is present) but the amount of delay was not linked to frequency of the monosyllable, nor frequency of the polysyllable. A chi square analysis suggests that the distribution of PPs was not random. What can one offer as an interpretation of aphasic performance?

The aphasic subject's performance suggests a general impairment in the processing mechanism; be it at the activation or inhibition stages. Where normal subjects appear to show competition on the emergence of polysyllabic hypotheses from highly activated

---

[11]Short words are more common.

(frequent) monosyllabic competitors, the aphasic subject's performance does not show any delay in polysyllabic emergence as a result of differential activation of frequent and rare monosyllables. This could also be interpreted as hyperactivation of both sets of monosyllabic hypotheses, which might also level the difference between frequent and rare monosyllabic candidates. A hyperactivational account does not fit with the secondary data reported: the commitment to the target polysyllable. The aphasic shows commitment to the target polysyllable more quickly after the initial adoption of a polysyllable (at the poly-point) than does the normal subject. If the monosyllables had been over activated one would predict that their decay or susceptibility to competitors would have been slower than that of the normal subjects. In addition, the aphasic shows an effect on monosyllable frequency on the delay between adopting a polysyllable and being committed to it: the rare monosyllables show less of a delay. This is in direct contradiction of a hyperactivational account.

The data are more compatible with a 'slow rise time' hypothesis. Prather et al. (1991) offer an explanation for the processing in aphasia based on the concept of 'Slow rise time'. Their auditory priming investigation suggested that while Broca's aphasics do not access the variety of potential meanings of polysemous words, Wernicke's aphasics do. Processing is still impaired however, because of the inability to correctly select between correctly activated candidates. The Broca's aphasics only appeared to access the most frequent contextually relevant words. In this current experiment, the fluent aphasic shows delayed adoption of the polysyllabic hypotheses compared to normal subjects. The aphasic is slow to integrate the bottom-up information which indicates the possibility of a polysyllabic hypothesis and the adoption is delayed.

7.9.3. Summary Conclusions

The normal subjects' adoption of polysyllabic hypotheses were strongly affected by the monosyllable competitor frequency. This monosyllable frequency effect was not directly retained in the aphasic listener's processing. Both frequent and rare hypotheses act as equal competitors for emerging polysyllables unless the number of monosyllabic competitors are taken into account. Until the point of adoption of a polysyllable, the polysyllable cohort features do not appear to compete as robustly as those pertaining to monosyllable candidates.

A.L.'s performance is best described by stating that his adoption of polysyllabic competitors is globally delayed because their activation rises more slowly than is the case in normal processing. In addition, when the number of monosyllable competitors are taken into account, the role played by the frequency of the monosyllable competitors is evident.

Chapter 8

Interaction of Open- and Closed-Class competitors in segmentation choice: Experiment 5

8.1. Open- and Closed-Class Words

The closed-class of words consists of around 200 grammatical items including determiners, auxiliaries, quantifiers, pronouns, conjunctions and some adverbs along with bound inflectional morphemes. (Petocz & Oliphant, 1988). Nouns, verbs, adjectives and the majority of adverbs comprise the open-class of words. English open- and closed-class words differ in prosodic terms; 90.5 % of closed-class words have a weak initial syllable[1] (Cutler & Carter, 1988). Sixty-six percent of closed-class words in one sample contained only weak syllables, while only 10% of open-class words comprised only weak syllables (Shillcock, Bard & Spensley (1988)). It is also widely claimed that the two word classes are processed qualitatively differently (Bradley & Garrett, 1979) and that they present different processing difficulties for impaired listeners and speakers (Bradley et al., 1980). It is in this final aspect - the question of processing difference - that there is most variation in the literature.

[1]Weak syllables are defined here as those containing a schwa or reduced vowel.

8.2. Processing Open- and Closed-Class Words

8.2.1. Frequency Effects in Open- versus Closed-Class Words

Bradley and Garrett (1979) reported that normal subjects show a frequency effect for visual lexical decisions on open- class words but that no such effect obtains for closed-class words. When aphasic subjects performed the task, the Wernicke's aphasics' performance echoed the normal behaviour. Broca's aphasics, however, showed a frequency effect for both open-and closed-class words. That is, Wernicke's aphasics processed closed-class words in the same way that the normal readers did - the speed or accuracy of processing such a word is not affected by its frequency. Broca's aphasics, on the other hand, processed closed-class words differently to normals - the Broca's aphasics treated closed-class words as if they were open-class words - processing was affected by frequency. Bradley posited that this constituted evidence of a dual-route mechanism for lexical access. She proposed that one route, normally reserved for open-class word retrieval, is frequency sensitive. A second, she suggested, is normally used for closed-class lexical access and is not frequency sensitive. Bradley posited that agrammatics have lost the ability to use the second route and so use the first to access all words regardless of form class.

Subsequent studies have not always concurred with Bradley et al.'s findings or their controversial dual route interpretation. Gordon & Caramazza (1982) carried out a set of visual lexical decision tasks similar to that of Bradley et al.. They failed to find an appreciable difference in normal behaviour to open- and closed-class words with regard to frequency sensitivity. Both word classes showed reaction time frequency sensitivity for words with frequencies less than 316/million. At higher frequencies, there were few suitable open-class materials available and closed-class words showed "an almost-flat function of the reaction time versus the logarithm of the frequency". That is, closed-class words are overrepresented at the higher end of the frequency spectrum. This results in a "saturation" effect which means that correlations between reaction time and frequency will always be less strong for closed-class words than for open-class words.

In recognition of the problem of finding materials sets to compare open- and closed-class items, Gordon & Caramazza (1983) further investigated the open- and closed-class distinction by varying subject groups rather than stimulus sets. Gordon and Caramazza claim that comparing closed class sensitivities of agrammatics and non-agrammatics allows insight into normal and non-normal closed-class processing while obviating the problems of finding controlled sets of open- versus closed-class materials. The usefulness of such a paradigm rests on the validity of the claim that agrammatics process closed-class words differently from non-agrammatic aphasics. The assumptions regarding the processing capacities of the subject groups, are not rigorously defended.

The subject groups chosen by Gordon and Caramazza were agrammatic, fluent nonagrammatic (i.e. reputedly normal with regards closed-class functioning) and nonfluent with indeterminate grammatical ability (undetermined as to whether they would treat closed-class words as a distinct class from open-class words). They report no difference between processing accuracy or latency of closed and open-class words as a function of word frequency for any of the subject groups. They conclude that there is no difference in the agrammatics' and nonagrammatics' closed-class frequency sensitivity. They are keen to remind the reader that this does not indicate that there are not processing differences between the word classes, simply that agrammatism does not result from an impaired frequency insensitive closed-class system.

8.2.2. Data from the auditory domain

In the auditory domain, lexical decision tasks have shown that for normal subjects, frequency sensitivity extends to both word classes (Matthei & Kean, 1989). That is, frequent words are responded to more quickly regardless of the word's class. These effects persist even when the effects of duration of word and cohort size were partialed out. Some differences between performance with open- and closed-class stimuli were found. When frequency was controlled (i.e. held constant), there was a cohort size effect for open-class words but not for closed-class items. An increase in cohort size was correlated with lexical decision times for open-class items. It was argued by Matthei and Kean, however, that a separate lexicon of only closed-class items would be accessed when a closed-class stimulus was presented so cohorts were measured in two ways; first counting all members, then counting only closed-class members. Even when the cohorts for the closed-class items are restricted to closed-class membership there was no significant correlation with reaction time. However, this may be because of the smaller range of frequencies for closed-class words, and smaller sets consisting mainly of monosyllables.

Segui et al. (1982, 1987) find a comparable frequency effect with normal subjects for open- and closed-class French words: the frequency effect obtains for both classes. Indeed, Dutch (Kolk & Grunsven, 1981), and German (Friederici & Heeschen, 1983, Heeschen et al., 1984) studies also fail to replicate the difference in open- and closed-class processing reported by Bradley et al.

8.2.3. Discrepancies between findings

One explanation for the discrepancy between Bradley et al.'s findings and others is couched in terms of frequency overlap of the open- and closed-class sets. Bradley's closed-class materials have been criticised for having too many very high frequency items (Segui et al., 1987). Gordon (1983) argues that this imbalance causes a saturation point to be reached in reaction times to words over frequencies of 319-399/million. Note that Matthei & Kean when working in the auditory domain, do not find this 'floor' effect. Segui et al. (1987) find that, although in general frequency effects are found for open- and closed-class words, very high frequency words from both classes (greater than log frequency 2.6) did not show frequency effects.

In sum, when stimuli from both classes are strictly matched for frequency, open- and closed-class words elicit faster lexical decision times for frequent words than for rare. If one can assume that lexical decision tasks reflect lexical access (but c.f. Balota & Chumbley 1984) then one could claim that lexical access to both open- and closed-class words is frequency mediated. Although this is not tantamount to claiming that both open- and closed-class words compete on equal terms for access, the literature detailed above provides little evidence that open- and closed-class words provoke different processing patterns.

8.2.4. Interference effects

Measures other than the relationship between item frequency and lexical decision times have been used to explore the differences between open- and closed-class processing. An alternative method is to measure the extent to which the presence of a word initial embedded real word interferes with the lexical decision for nonwords. Interference effects from open-class and closed-class words are found to differ. Visual lexical decisions to nonwords headed by open-class words (e.g. *footmilge*) are slower than when the nonword does not contain a word initial open-class item *mowdflisk* [2] (Forster, 1976, (reported in Shapiro & Jensen, 1986), Taft & Forster, 1976). The same is not true for nonwords headed by closed-class words (e.g *sucherty*) which elicit reaction times comparable with nonwords containing no word initial item (Bradley, 1978). That is, for normal subjects, closed-class words do not interfere with nonword lexical decision. Broca's aphasics show the same reaction times for lexical decisions to both open- and closed-class headed nonwords (Bradley & Garrett, 1979). Bradley interprets this as evidence that the Broca's aphasics suffer interference effects from both word classes. Replication of the interference task with normal subjects in the auditory domain yielded results comparable with those of Bradley et al.; reaction times to nonwords headed by open-class items were delayed compared to baseline responses while RTs to closed-class headed nonwords showed no such interference (Matthei & Kean, 1989). It is not reported whether such factors as cohort size or other indicators of competitor strength were balanced across materials. If the cohort sizes were to correlate with word class then it might be invalid to attribute differences in processing time to a word class effect.

When a lateralised word reporting task was performed by normal subjects, a right visual field advantage is found overall for word spotting. That is, words presented to the right visual field (which corresponds to the left hemisphere) are spotted faster than those presented to the left visual field (Bradley & Garrett, 1983). With the right visual field, open-class words had an advantage over closed-class words, whereas no processing difference between the two was found in the left visual field. Bradley proposes that this adds further evidence to the claim that open- and closed-class words are processed via separate specialised recognition devices which are housed in the left hemisphere, and

---

[2]Note, however, that the example provided by Shapiro does contain a real word - *mow*.

that the damaged processor uses a non-specialised route (which may be housed in the right hemisphere). Shapiro & Jensen (1986) extend this paradigm by looking for frequency effects in the lateralised word reporting tasks. The investigation yields a greater than previously reported difference between closed- and open-class headed words for both right and left visual field. Only the RVF, which implicates the left hemisphere, shows a significant difference. Shapiro concludes that the data support an asyntactic view of the role of the right hemisphere in processing. According to Besner (1988) a general claim is that any finding which validly holds in a laterality paradigm, can be replicated in foveal presentation. Besner uses this claim to support his result: when the open- versus closed-class word identification task was replicated by presenting the stimuli at fovea rather than in a lateralised manner (Barry, 1981, Besner, 1983, Besner, 1988), no difference in open- and closed-class word recognition was found.

The validity of these data is questionable. Petocz & Oliphant (1988) suggest that several uncontrolled variables in the experimental materials used by Bradley et al. and Shapiro & Jensen confounded the results and, cumulatively, invalidate them. Petocz & Oliphant show that a different pattern of results obtain when phonological interference, pseudohomophony of the initial syllable (i.e. whether a token is a non-word (e.g. *brane*) which is homophonous with a real word (*brain*) or not), orthographic interference, and word initial cohort size are controlled for. Although open-class items lead to longer delay in nonword lexical decision times than closed-class words do, closed class items also show interference significantly longer than baseline. Matthei and Kean (1989) conclude that the difference in performance with open- and closed-class stimuli is the result of post-access events. They suggest that lexical decision tasks can neither support nor disconfirm hypotheses regarding whether or not open- and closed-class items undergo different processing.

8.2.5. Cross-modal Priming

A third source of data on open- and closed-class processing differences is cross-modal priming. Shillcock & Bard (forthcoming) report data from a series of such experiments in which they tested the priming strength of homophonous words where one meaning was open-class (e.g. *wood*) and the other closed (e.g. *would*). The homophone is presented in a closed class context such as:

John said that he didn't want to do the job, but his brother **would** *as I later found out.*

and an open-class context:

John said that he didn't want to do the job with his brother's **wood** *as I later found out.*

Reaction times to the presentation of a word like *timber* were facilitated after the open-class context presentation, but not after the closed-class presentation; *wood* primed *timber*, but *would* did not. Having confirmed that the pronunciation of the homophones was indistinguishable, and that the results were not related to word frequency, the investigators conclude that a contextual constraint operates to inhibit the emergence of the open-class homophone once the closed-class mate has been activated. The degree to which this constraint inhibits priming is governed by contextual constraints. The extent to which informational encapsulation is supported, is tempered by this and earlier results (Tannenhaus et al., 1979). When homophony exists between two open-class competitors, priming does occur even when the form class differs. For example; *They all rose* primes *flower*. That is, the verb *rose*, primes an associate of the noun homophone. This implies that both meanings of the word have been, at least momentarily, activated. Conversely, when the homophones are presented in context and are from different word classes (i.e. open- vs closed-class) as is the case with *would* and *wood*, there is no priming of associates of the opposite class homophone. The implication here is that only the contextually appropriate word is activated. This suggests that word class does act as a way of delimiting the search space in lexical access in concert with top-down syntactic activation.

Cutler (1993) offers an additional explanation for such findings. She claims that listeners benefit from the correlation between syllable strength and word class in determining word class. Her argument is in essence, as follows. The processing of open-class words is more complex than that of closed-class words. For a proportion of open-class words (e.g. in cases of homophony) the contextually appropriate meaning must be selected from multiple activated hypotheses (see Tannenhaus, 1979, Shillcock and Bard, forthcoming). As it is time consuming to find which of the briefly activated hypotheses is appropriate, the sooner the process begins, the better. Strong syllables, which are most prevalent in open-class words facilitate such early processing. Closed-class words have little context dependent variation and most of the information stored with their lexical entry would relate to syntactic functioning. Thus, the difference between the processing of the two word classes is related to the amount of semantic work required to correctly parse such words.

Cutler tentatively posits partitioning the lexicon to reflect this semantic-based split. Rather than assigning a word to a particular class on the basis of extendibility (open - extendible) or (closed not extendible), she suggests that a more psychologically real distinction would be one based on semantic complexity; *"words which could be ambiguous, polysemous, or contextually variant in semantic effect versus words which have minimal variability of this kind"*. This partitioning, however, would not account for the findings of Shillcock (1992) reported above in which some homophonic words (where both words are open-class *rose* as noun and verb) do engender multiple activation, whereas others (where one word is closed-class, *would* and the other is open-class, *wood*) do not.

8.2.6. Predictions

In the following investigation I consider whether the kind of syntactic top-down effects to the lexicon suggested by Shillcock and Bard's results, interferes with the recognition of words which belong to the opposing form class. Closed-class words receive confirmation from top-down syntactic level as functional projections would all be activated along with the lexical entry. The prediction is that, having accessed the closed-class hypothesis, the activation of the array of syntactic markers attached to it will make it more difficult for the listener to lose the hypothesis in favour of a longer open-class one. The same degree of difficulty will not be experienced in releasing open-class early hypotheses. When words are presented in isolation the listener has no prior context to predict either a closed- or open-class preference. It should be noted, however, that isolated presentation is not strictly a sytactically null context - it effectively places the stimuli in utterance initial position.

Both the open- and closed-class monosyllables used as stimuli embedded items are frequent. Activation models (Cohort, 1987, 1990) would support the prediction that as frequent words, all of the monosyllables would enjoy (a) fast rise time, (b) be strong competitors, and (c) would delay the emergence of competing polysyllables. If the closed-class competitors are more syntacticaly supported by greater top-down syntactic prediction, the closed-class representations will receive more representational support and will dominate polysyllabic hypotheses for longer than will frequency equivalent open-class monosyllables.

The selection of the target word requires integration of the acoustic information indicating the polysyllabicity of the word and the lexical biases for the allocation of word boundaries. On-line integration of information has been shown to present problems for aphasics, who, at single word level do not present with severe or specific deficits (Kilborn, 1991, Tyler, 1992). It is predicted that when polysyllabic and monosyllabic hypotheses compete for recognition, the aphasic's activation of hypothesis will not enjoy the same rapid rise time as the normal subject's hypotheses. This will cause problems for integration. Although fluent aphasics do not typically have recognisible closed-class deficits, impaired ability to integrate multiple sources of competitor information will be reflected in their failure to show the sort of closed- versus open-class competitor processing differences that are predicted for the normal subjects. Degradation of processing, even if not focussed on the processing of closed-class items, may lead to an inability to integrate the top-down syntactic features which I predict are used by normal subjects, and render the processing of closed-class words different to processing open-class words. The interaction of the multiply activated hypotheses requires the integration of substantial amounts of lexical information in order that recognition be resolved. I predict that the aphasic subject will not be able to integrate the available information sufficiently quickly. This will not allow the aphasic listener to delimit the lexical search space in a sufficiently focussed manner and a general delay in processing will result.

8.3. Methodology

8.3.1. Materials and Design

Table 8-1: Experiment 5: Example of materials

Example Cells for Open- versus Closed-Class Gated Embedded Word Detection Experiment			
FREQUENT POLYS CLOSED-CLASS MONOSYLLABLE **FPCM**	*FREQUENT POLYS OPEN CLASS MONOSYLLABLE* **FPCM**	*RARE POLY CLOSED-CLASS MONOSYLLABLES* **RPCM**	*RARE POLYS OPEN CLASS MONOSYLLABLE* **RPOM**
major/may	paper/pay	sheepskin/she	scenery/see

The following 2 x 2 design was used: Monosyllable type (2 levels; open-class, closed-class) x Polysyllable type (2 levels; frequent, rare). Materials were crossed to generate four cells (Frequent Polysyllables with open-class monosyllable pairs (FPOM); Frequent Polysyllables with closed-class monosyllables (FPCM); Rare Polysyllables with open-class monosyllable (RPOM); and Rare Polysyllables with closed-class monosyllables (RPCM). Each cell contained 8 pairs of stimuli (e.g. FPOM contains 8 pairs of words of the sort *paper* and *pay*). A latin square design was used to generate two listening conditions. Subjects in each listening conditions heard only one member of each pair (e.g. In Listening Condition 1 subjects heard *paper*, in Listening Condition 2 subjects heard *pay*). Normal subjects were matched across listening conditions. The aphasic subject (A.L.) heard all tokens with a period of one month between presentation of each listening condition. A set of eight practice items, containing the same mixture of open- and closed-class, poly- and monosyllabic words as in the experimental cells was also constructed. The same practice sets were spliced onto the start of each experimental tape. Experimental materials are listed in Appendix E.

8.3.2. Recording of Materials

The materials were presented to the speaker individually on a BBC-B microcomputer monitor. Individual presentation elicits read speech which does not contain "list intonation" and phonation patterns which potentiate differential intelligibility and prosodic identity of words depending on position in the list. Materials were recorded and presented without context[3]. The materials were recorded directly onto Digital Audio Cassette tapes in a sound proofed recording studio. Each item was digitised at a rate of 16KHz using the Entropic Signal Processing System through the Xwaves speech analysis programme. After digitisation, tokens were spliced at 30ms and then into successively longer portions, each 30ms longer than the previous one[4]. Gating was governed by a C programme; the programme cut each token into 30 ms gates, ramped the final 2 ms of each gate to eliminate perceived clicks (which may bias or hinder perception of the stimuli) and alternated gates with single tones, indicating the onset of the next gate. A gap of 1500 ms was inserted between each gated portion. The onset of each new word was signaled by a double tone.

One pseudo-randomised order was maintained across both listening conditions. Where the polysyllabic word from one cell occurred in Listening Condition A , its monosyllabic mate occurred in Listening Condition B, and vice versa. The position of any monosyllable in one list was governed by the position of its polysyllabic carrier in the opposing list; for example, as the first item in list A *cumbersome*, list B's first item is *come*. Two practice items were presented before each experimental session.

---

[3]It has been reported that listeners can predict the length of subsequent words from prosodic patterns in the initial stages of an utterance (Grosjean, 1983). The potential problems which arise from preceding the tokens with a neutral sentence context (which may miscue listeners for word length) or using same-time recorded leading contexts (which may give prosodic cures to length of following token) were avoided by recording and presenting the tokens in isolation.

[4]A pilot study involved presentation of 50ms fragments which the subject interpreted with ease, suggesting that the smaller, more illuminating gate would be feasible. Gates of 30ms are frequently used in experimentation with non-aphasic subjects for investigation of lexical access phenomena.

8.3.3. Procedure

The gating paradigm was again adopted. The set induction procedure, practice sessions and task proper was identical to that followed for Experiment 4 (See Chapter 7). In brief, the listeners were presented auditorially with fragments of words, each fragment 30ms longer than the previous one, until the entire word has been presented. The listener makes a guess as to the material's identity after each fragment.

8.3.4. Subjects

All subjects were identical to those used in Experiment 4 (See section 7.7.15). That is, one fluent aphasic (A.L.) and 8 ageing normal controls.

8.4. Results

The primary aim of the present investigation, was to determine polysyllable and monosyllable competitor effects from the point of view of polysyllable frequency and monosyllable word class.

The first analysis was of the performance of both subject groups when listening to the polysyllabic members of each pair. The specific question addressed is how the adoption of polysyllabic hypotheses is affected by the nature of the polysyllables and monosyllables in the cohort.

8.4.1. Does the aphasic perform normally?

The first objective is to compare the poly-lag[5] for the normals and the aphasic subject. The poly-lags of the aphasic responses (mean = 64.2ms) and the control mean response (mean = 45.9ms), when compared using a *t-test*, proved insignificant (t = 1.57, df 28, p= 0.1272). A trimmed *t-test* in which 2 outliers were removed by the statistical programme showed a marginally significant difference between the two groups (normal mean = 44.4ms, aphasic mean = 64.5ms; t = -2.00, df 26, p = 0.0565). The null hypothesis that the two samples are acting as one group, can not be robustly supported.

---

[5]Recall that poly-lag is the difference in number of gates between (a) the objective point of divergence from acoustic information commensurate with that of a monosyllabic hypothesis and (b) the adoption of polysyllabic word guesses. For a full definition of poly-lag, see section 7.8.

Given that there has been so little consensus in the literature on the subject of open- versus closed-class processing by aphasics, it is wise to test the difference between the normals and the aphasic subject on the two word classes separately. It may be that A.L.'s performance resembles the normals' in one subset of materials but not in the other. When the aphasic's performance on items with open-class embedded monosyllables and closed-class embedded monosyllables are considered as separate groups we find that a difference in performance emerges for the open-class words only. When the aphasic data is compared with mean normal performance on closed-class materials, the null hypothesis is not discredited (normal mean = 69ms, aphasic mean = 69ms; $t = 0.25$, $df = 12$, $p = 0.8$). Performance on open-class words however yields a significant result (normal mean = 27.3ms, aphasic mean = 63.6ms; $t = -2.35$, $df = 15$, $p < 0.05$). That is, the aphasic's performance is not systematically different to that of normals on closed-class words but differs systematically on the open-class words. This is because the aphasic poly-lag is systematically later than the normals' on the open-class materials but randomly different to the normals' on the closed-class words.

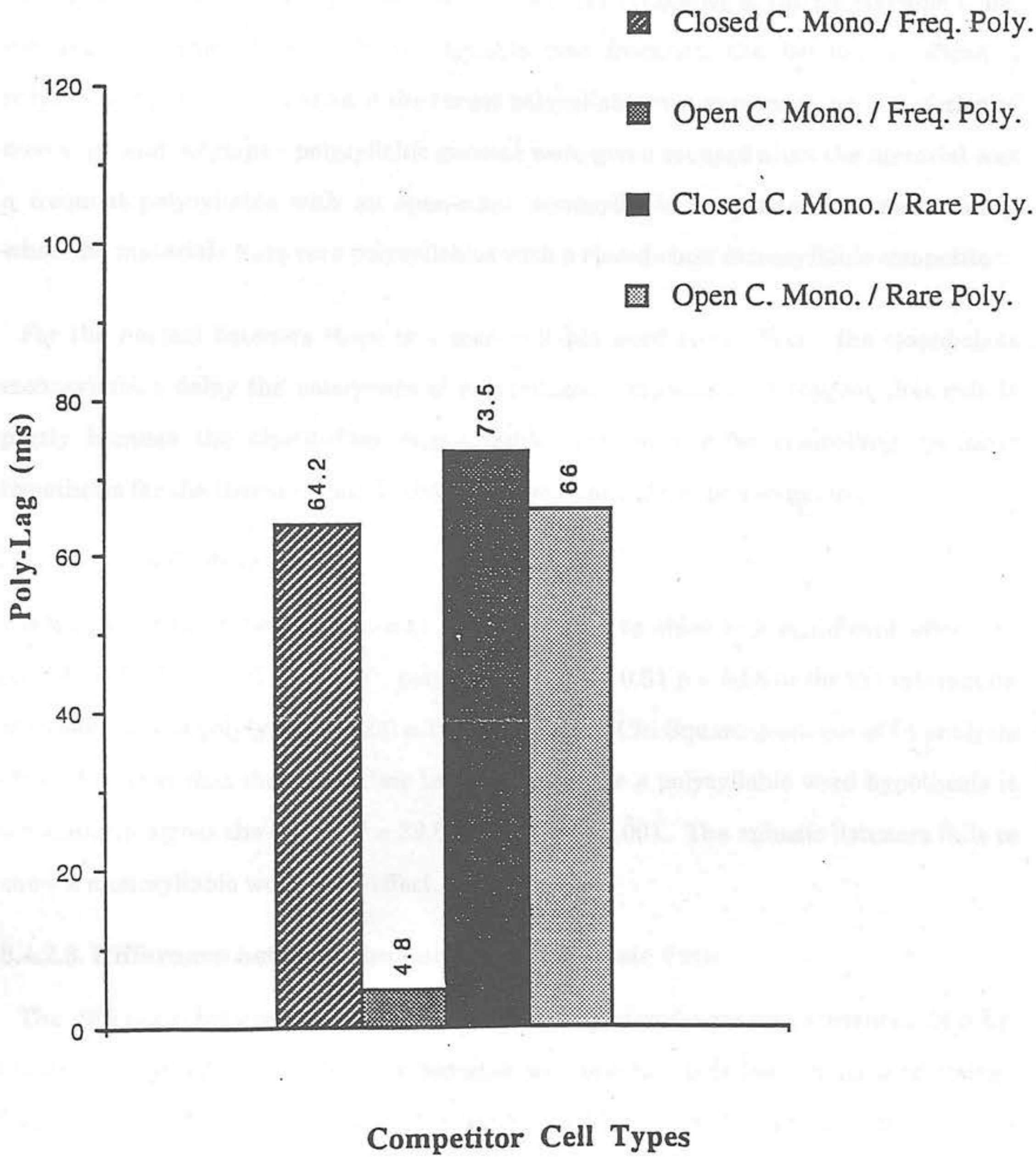
8.4.2. Does monosyllabic word class affect adoption of polysyllabic guesses?

8.4.2.1. Normal ageing data

The data from the normal subjects was analysed using a two-way ANOVA. The effect of monosyllable word class was significant - closed-class monosyllabic embedded words delayed the adoption of polysyllabic hypotheses (F_1 (1, 24) = 11.37, $p < 0.0025$, F_2 (1, 23) = 6.22 $p < 0.02$, MinF'(1, 42) = 4.02055, $p < .05$). The effect of polysyllable frequency (polytype) was significant in the by-subjects analysis (F_1 (1, 24)= 6.51 $p < 0.02$.), but not in the by-materials analysis (F_2 (1, 23) = 2.34, $p = 0.14$). The interaction between the two variables was not significant in the by-subjects analysis ($F_1 = 3.94$, df (1, 24), $p = 0.0588$.), but was in the by-materials analysis ($F_2 = 6.35$ df (1, 23) $p < 0.02$.). (See Figure 8-1)

A *post-hoc* (Scheffé) test shows that the poly-lags for the frequent polysyllables with the closed-class monosyllabic competitor were significantly shorter than those for the rare polysyllables with the closed-class monosyllabic competitor. In addition, the poly-lags for the frequent polysyllables with the closed-class monosyllabic competitor were

Figure 8-1: Adoption of polysyllable lexical hypotheses by Normal Subjects: Open-class versus closed-class competitors



significantly shorter than for the frequent polysyllables with the open-class monosyllabic competitors. These results are in accord with the notion that the word class of the monosyllable competitors has the strongest effect on the listeners' adoption of polysyllable hypotheses.

Other less robust effects pertain to the effect of the frequency of the polysyllable being listened to - when the target polysyllable was frequent, the listener proffered a polysyllabic guess sooner than if the target polysyllable was rare; and the interaction of monotype and polytype - polysyllabic guesses were given soonest when the material was a frequent polysyllable with an open-class monosyllable competitor and most slowly when the materials were rare polysyllables with a closed-class monosyllable competitor.

For the normal listeners there is a monosyllable word class effect - the closed-class monosyllables delay the emergence of polysyllabic competitors. I suggest that this is partly because the closed-class monosyllables set up a more compelling syntactic hypothesis for the listener than do the equivalent open-class monosyllables.

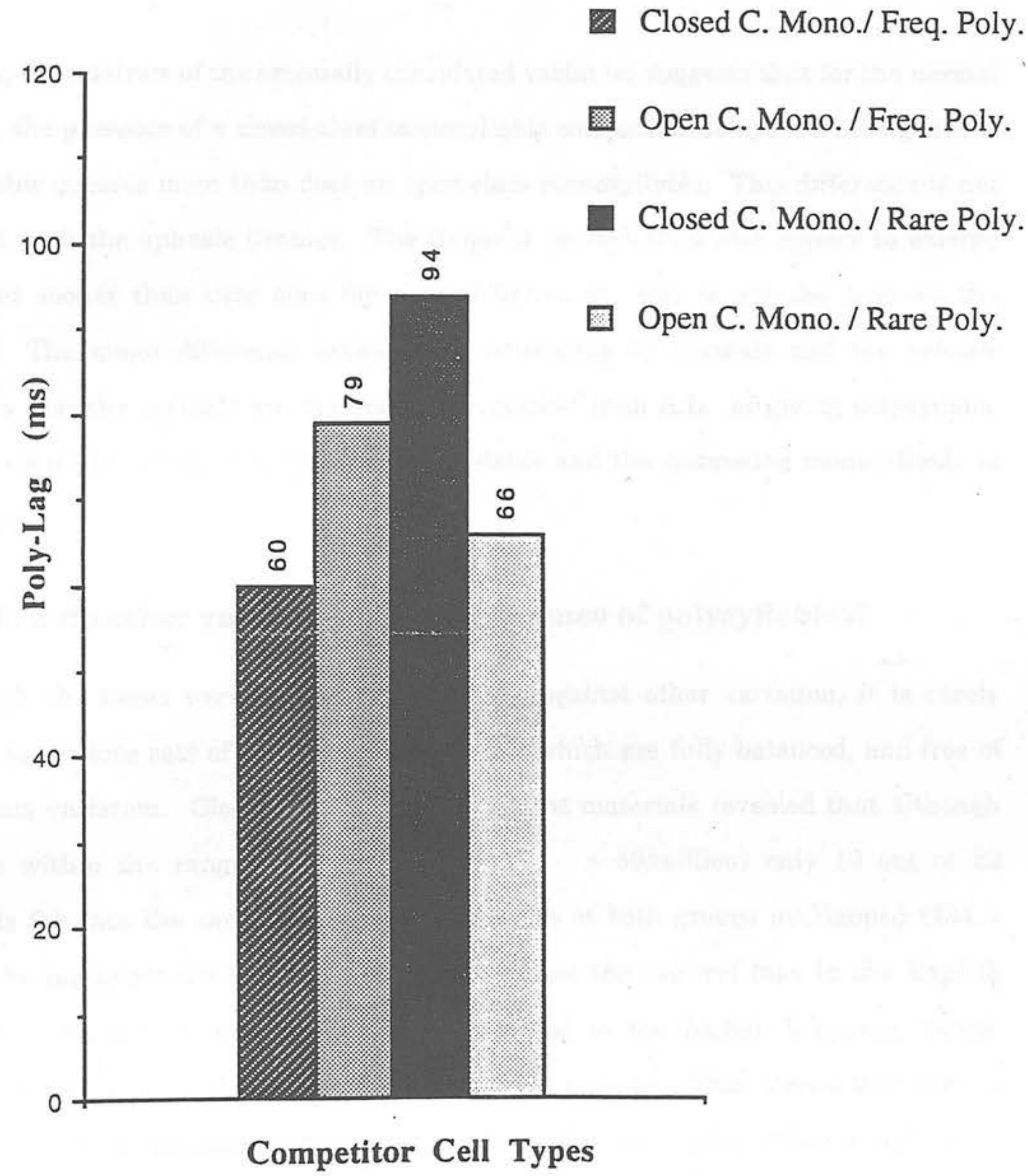
8.4.2.2. Aphasic data

With the aphasic data, a two-way ANOVA failed to show any significant effects of monotype F (1, 23) = 0.0 $p = 0.97$; polytype F (1, 23)= 0.31 $p = 0.58$ or for the interaction of monotype and polytype F (1, 23) = 1.26 $p = 0.28$. A Chi Square goodness of fit analysis shows however that the mean time taken to stipulate a polysyllabic word hypothesis is not uniform across the cells. $\chi^2 = 39.87$, $df = 3$, $p < 0.001$. The aphasic listeners fails to show a monosyllable word class effect. (See 8-2)

8.4.2.3. Difference between the normal and aphasic data

The difference between the aphasic and normal performances was measured in a by-materials ANOVA; the dependent variable was (*normal poly-lag - aphasic poly-lag*). The question asked was, do the independent variables cause the normal poly-lags to be shorter than those of the aphasic? The monosyllable word class did not significantly account for the difference between the aphasic and normal group performance (F (1, 23) = 1.99 $p = 0.17$); nor did the effect of polytype (F (1, 23) = 0.40 $p = 0.53$). The interaction between monotype and polytype did have a significant effect on the difference of the two listener types (F (1, 23) = 7.49 $p < 0.02$). A *post-hoc* (Scheffe) test shows that only when

Figure 8-2: Adoption of polysyllable lexical hypotheses by a Fluent Aphasic Subject: Open-class versus closed-class competitors



the monosyllable is open-class and the polysyllable frequent, do the normals systematically have shorter poly-lags than the aphasic. In all other cells, the poly-lags do not systematically differ. The mean poly-lag of the frequent polysyllables with the closed-class monosyllabic competitors is significantly longer than that of the frequent polysyllables with the open-class monosyllabic competitor cell. In addition, the mean poly-lags for the rare polysyllables with the open-class monosyllabic competitor were significantly longer than those of the frequent polysyllables with the open-class monosyllabic competitor cells.

In sum, the analysis of the originally considered variables suggests that for the normal subjects, the presence of a closed-class monosyllable competitor delays the emergence of polysyllabic guesses more than does an open-class monosyllable. This difference is not apparent with the aphasic listener. The frequent polysyllables also appear to emerge somewhat sooner than rare ones for normal listeners: this is not the case for the aphasic. The major difference between the processing by normals and the aphasic subject is that the normals are systematically quicker than A.L. at giving polysyllabic guesses when the target is a frequent polysyllable and the competing monosyllable is open-class.

8.4.3. How do other variables effect emergence of polysyllables?

Although the items were largely controlled for against other variation, it is rarely possible to produce sets of investigative materials which are fully balanced, and free of extraneous variation. Closer analysis of the current materials revealed that although all were within the range of frequent words (i.e. > 30/million) only 12 out of 32 materials fell into the range where the frequencies of both groups overlapped (234 > 395). The materials used in this experiment reflect the natural bias in the English lexicon for closed-class words - they are clustered in the higher frequency bands. Frequency was correlated with word class ($r = .63$, $p < .05$). This means that serious consideration must be given to the question of whether word class makes a significant independent contribution to accounting for poly-lag or whether the result is due to a word class/frequency confound.

Multiple regression analysis was employed to examine the role played by the frequency of the monosyllable as well as by additional variables. This allows us to disentangle the correlated variables and uncover previously obscured causative factors[6]. Because the field of word recognition is a mature one, it is possible to establish a principled list of predictor variables for the estimation of poly-lag. The initial list of predictor variables is set out in Table 8-2. Table 8-3 shows descriptive statistics on the independent variables selected, along with descriptive data on the dependent variables, that is, the poly-lag data for the normal group and the aphasic subject.

Table 8-3 shows that the poly-lag for the normal subjects ranged from -5.00 gates (equivalent to -150 ms) before the divergence point to 8 gates (240 ms) after; the mean poly-lag was 1.58 gates (47.4 ms) after the divergence point with a standard deviation of 2.60 gates (78 ms).

This set of 8 predictor variables together accounted for a significant 24.5% of the variance in the poly-lag ($R^2 = 0.24$ $F(10, 98) = 3.176$ $p = < 0.0015$). For the aphasic subject the poly-lag ranged from -3.0 gates (90 ms) before the divergence point to 7 gates (210 ms) after; the mean poly lag was 2.14 gates (64.2 ms) with an S.D. of 2.12 (63.6). This set of variables accounted for 49% of variance ($R^2 = 0.49$, $F(10, 17) = 1.620$ $p = < 0.1834$).

8.4.3.1. Univariate correlations: relations between independent variables

First a set of simple (univariate) correlations was run to establish the relationships between each independent variable and the dependent variable.

Word class is correlated with monosyllable frequency ($r = .64$, $d.f. = 107$, $p < .005$)

8.4.4. Collinearity between predictor variables of poly-lag

The matrix of the univariate correlations showed that some of the predictor variables are correlated with each other. It is suggested that if variables intercorrelate to a value $r < .8$, one of the independent variables should be eliminated (nie75). Although collinearity poses considerable problems for the validation of multiple regression analyses, it is often recommended that the problem can be resolved through elimination of the variable least able to predict the variance in the dependent variable (graesser84).

[6]See Chapter 4, Pg 74 for description of the general multiple regression analysis rationale.

Table 8-2: Experiment 5 Key to independent and dependent variables

Where...	*Is*
CONTROL	Poly-lag data for normal subjects
APHASIC	Poly-lag data for aphasic subject
MONOFREQ	Frequency of the embedded monosyllabic word
COHCUMFQ	Cumulative frequency of the cohort
COSIZE	Number of words in the cohort
NOMONS	Number of monosyllabic words in the cohort
MCUMFREQ	Cumulative frequency of the monosyllabic words
WDCLASS	Word class (1 = closed-class, 0 = open-class)
PFREQ	Frequency of the target polysyllabic word
TOPMS	Number of monosyllabic words more frequent than any polysyllabic word in the cohort
CFTOPM	Cumulative frequency of TOPMS
TMHP	Difference between the frequencies of: - The embedded monosyllabic word and the cohort's highest polysyllabic word.
HMHP	- The cohort's highest monosyllabic word and its highest polysyllabic word.
TMTP	- The embedded monosyllabic word and the target polysyllabic word.
HMTP	- The cohort's highest monosyllabic word and the target polysyllabic word.
HPOLYFQ	The most frequent polysyllabic word in the cohort
NOPOLS	The number of polysyllables in the cohort.

In this instance, cumulative frequency of monosyllables correlates to a degree $r = .90$ with cohort cumulative frequency. As cumulative frequency of monosyllables is marginally more useful at predicting poly-lag, it is retained and cohort cumulative frequency removed. In addition, TMHP, HMHP, TMHP and HMTP are all intercorrelated. As HMTP is the best predictor of the dependent variable, this is retained and the others are eliminated from further investigation. In some cases the elimination of one of a correlated pair of variables was not desirable (e.g. it is of theoretical interest to know the contribution played by both cohort size and number of

Table 8-3: Experiment 5 Descriptive statistics of independent and dependent variables

Variable	*Mean*	*S. D.*	*Coefficient of Variation*	*Min*	*Max*
CONTROL	1.5780	2.6009	1.64825	-5.00	8.00
APHASIC	2.1429	2.1207	0.98966	-3.00	7.00
MONOFREQ	294.2110	151.8984	0.51629	34.00	500.00
COHCUMFQ	714.6515	463.7957	0.64898	112.00	1866.00
COSIZE	49.8807	48.8117	0.97857	4.00	179.00
NOMONS	6.9725	4.7130	0.67594	1.00	18.00
MCUMFREQ	504.6974	361.9697	0.71720	82.00	1301.0
WDCLASS	0.4679	0.5013	1.07135	0.00	1.00
PFREQ	38.0367	42.7592	1.12416	0.00	143.00
TOPMS	2.1284	1.7538	0.8240	0.00	6.00
CFTOPMS	443.6605	354.9217	0.7999	0.00	1299.00
TMHP	214.2294	166.9068	0.77910	-146.00	496.00
HMHP	218.4495	164.0273	0.75087	-104.00	496.00
TMTP	244.8716	158.2497	0.64626	-1.00	500.00
HMTP	249.0918	156.2097	0.62712	-1.00	500.00
HPOLYFQ	75.9082	60.7704	0.80058	1.00	222.00
NOPOLS	42.9083	45.6591	1.06411	1.00	162.00

monosyllables). Three pairs of intercorrelated variables are of this type: those pertaining to number of competitors total number of members of the cohort and number of monosyllables in the cohort; and those relating to polysyllable frequency, frequency of the target polysyllable and frequency of the highest polysyllable in the cohort and a third pair, the difference between the monosyllable and polysyllable frequencies and either the monosyllable frequency or polysyllable frequency individually. In these cases, only one of the highly correlated variables from each pair was included in any one hierarchy and replaced by its correlated mate in a separate hierarchy so that the separate role of each could be assessed. The independent contribution of lesser correlated factors can be assessed by manipulation in hierarchical analyses.

In order to establish the relative contribution to the variance of poly-lag, each independent variables must be considered simultaneously. To this end, a series of hierarchical multivariate correlations was performed. In each, the following general principals were observed. The order established reflected research relevance of the variables, while taking into consideration causal priority and the structural properties of each research factor. The aim was to discover how well each group of variables estimates the poly-lag, how much each single independent variable adds to the estimation of poly-lag already provided by the other variables, and to look at the cases when all but one particular variable are held constant statistically, to see how much of the poly-lag variance is accounted for by the given variable[7].

8.4.5. Contribution of variables to normal poly-lag variance

Word class is correlated with poly-lag for normal subjects ($r = .27$, $d.f. = 107$, $p < .005$). The correlation appears to reflect an association between a material's membership of the closed-class and a delay in the listeners' adoption of a polysyllabic hypothesis. This echoes the findings of the ANOVAs reported above. Word class and frequency are confounded: the closed-class embedded words tend to be more frequent than the open-class embedded words. It is possible, therefore, that effects attributed to word class may be spurious and better accounted for as effects of frequency or other independent variables. Their independent contribution can only be exposed in a hierarchical analysis.

8.4.5.1. Hierarchy 1

When monosyllable frequency and word class were partialled out together, there was a significant increase in the amount variance accounted for[9] ($R^2 = .09$, $F(2, 106) = 4.8$, $p < 0.01$). Word class accounts for a significant amount of variation in poly-lag ($\beta = 0.37$, $p < 0.01$). Monosyllable frequency, however, does not have any independent effect on poly-lag ($\beta = -.15$ $p > 1$.) The word class variable retains its significant standardised partial regression coefficient (β) as each of the remaining variables are added to the equation. That is, when all other variables are partialled out, word class continues to make an independent contribution to the account of the poly-lag variance.

---

[7]See Cohen and Cohen, (1983) for expansion on this rationale.

[9]That is, an increase from the account provided by monosyllable frequency alone.

Table 8-4: Hierarchies used in the Multiple Regression Analysis of the normal and aphasic poly-lag variance

Hierarchy	*Variables in order of entry*
Hierarchy 1	Monosyllable frequency, word class, number of monosyllables, cumulative frequency of the monosyllables, target polysyllable frequency, number of polysyllables.
Hierarchy 2	Monosyllable frequency, word class, number of monosyllables, cumulative frequency of the monosyllables, highest polysyllable frequency, number of polysyllables.
Hierarchy 3	Monosyllable frequency, word class, cohort size, cumulative frequency of the monosyllables, target polysyllable frequency.
Hierarchy 4	Monosyllable frequency, word class, cohort size, cumulative frequency of the monosyllables, highest polysyllable frequency.
Hierarchy 5	Word class, difference between the monosyllable and polysyllable frequencies, number of monosyllables, cumulative frequency of the monosyllables, number of polysyllables.[8]
Hierarchy 6	Word class, difference between the monosyllable and polysyllable frequencies, cohort size, cumulative frequency of the monosyllables.

The addition of the variable <u>number of monosyllables in the cohort</u> also significantly increases the amount of variance accounted for ($R^2 = .17$, F (3, 105) = 2.8, $p < 0.05$). The only variable making a significant contribution to this was <u>word class</u> ($\beta = 0.29$, $p < 0.02$). Its contribution has, however, apparently fallen (.37 > .29). This suggests than at least some of the word class effect is due to the difference in competitor sets for open- and closed-class words such as the number of monosyllable competitors it has. The addition of further individual independent variables does not significantly increase the amount of variance accounted for. When all variables in this equation are partialled out (<u>word class, monosyllable frequency, number of monosyllables, cumulative frequency of</u>

[8]All combinations of target and highest, monosyllable and polysyllable frequency differences were tested in these equations. The resultant data did not show any changes in significance of variables. The measurements used are the target monosyllable and target polysyllable frequencies.

the monosyllables, target polysyllable frequency, and number of polysyllables) 22% of the poly-lag variance was accounted for (R^2 = .23 $F(6, 102) = 4.98$, $p < 0.001$). Word class ($\beta = 0.40$, $p < 0.01$) and number of monosyllables ($\beta = 0.45$, $p < 0.01$) account for significant unique amounts of the variance.

8.4.5.2. Hierarchy 2

When the highest polysyllable in the cohort replaced the target polysyllable frequency in the analysis, the effect of word class remains the same. The analysis is identical to that of hierarchy 1 until the addition of the final variable (highest polysyllable in the cohort). When this variable is partialled out, the increase in account of variance is not significant (increase in R^2 = .02, F (6, 102) = 0.4, $p > 1$). When all variables are partialled out word class ($\beta = 0.34$, $p < 0.001$) number of monosyllables ($\beta = 0.54$, $p < 0.001$) and cumulative frequency of the monosyllables ($\beta = -.49$, $p < 0.01$), make significant contributions to the total (22%) variance accounted for.

8.4.5.3. Hierarchy 3

In this hierarchy the number of monosyllables variable was replaced by the variable of which it is a subset - number of members of the cohort or cohort size. The significance of the word class variable is retained in this hierarchy, but cohort size, unlike number of monosyllables, does not cause a significant increase in variance accounted for, or account for a significant unique proportion of any variance. The frequency of the target polysyllable variable accounts for a unique proportion of the small amount of variance accounted for. When all of the variables are partialled out together, only 15% of the poly-lag variance is accounted for. This suggests that cohort size is not as useful a predictor of polysyllable emergence as is number of monosyllabic competitors.

8.4.5.4. Hierarchy 4

When the highest polysyllable replaced the target polysyllable frequency only 13% of the variance in poly-lag is accounted for. The order of partialling out variables in this hierarchy is identical to that of hierarchy 3 until the addition of highest polysyllable frequency. The addition of highest polysyllable does not significantly increase the amount of variance accounted for. At this final stage in the addition of variables word class ($\beta = .41$, $p < 0.001$), is the variable making a significant independent contribution to the account of variance.

8.4.5.5. Hierarchy 5

Next I considered whether the the difference between the target monosyllable and polysyllable frequencies predicts the length of poly-lag. Again the addition of word class to the equation significantly increases the variance accounted for. No other variables significantly contribute to the account of significantly increase the amount accounted for. When all variables are considered; word class, difference between monosyllable and polysyllable frequency, cumulative frequency of the monosyllables, and cohort size, only 10% of variance was accounted for.

8.4.5.6. Hierarchy 6

When number of monosyllables was substituted for cohort size, all of the variables together accounted for 21% of the variance. The word class variable retained its effect ($\beta = 0.31$, $p < 0.01$). Apart from word class, the addition of no other individual variable significantly increased the amount of variance accounted for. The number of monosyllables was responsible for a unique amount of the variance accounted for ($\beta = 0.56$, $p < 0.00$).

8.4.5.7. Summary of results from the series of hierarchies

In summary of the normal subjects data, we can see that the best account of the variance is given by hierarchies 1 and 2 - the sets of variables which include word class, monosyllable frequency, number of monosyllables, cumulative frequency of the monosyllables, and either the target polysyllable frequency or the highest polysyllable frequency. That is, there were no significant changes in the account of variance when the target polysyllable frequency was substituted for the highest polysyllable in the cohort. In all of the hierarchies, the word class variable makes a significant contribution to a significant increase in account for poly-lags variance and retains its significance when all other variables are partialled out.

8.4.6. Aphasic poly-lag variance

The same set of hierarchical analyses were used to determine the effect of independent variables on the aphasic poly-lag.

Table 8-5 shows that no single variable appears to be associated with an increase in aphasic poly-lag.

Table 8-5: Correlation of predictor variables with Aphasic poly-lag

Variable	*Value of r*
WDCLASS	0.2112
MONOFREQ	-0.0731
POLYTYPE	-0.0686
COHCUMFQ	-0.0277
COSIZE	0.0933
MCOHLEAD	-0.3139
NOMONS	0.2668
MCUMFREQ	-0.0020

Word class is not correlated with aphasic poly-lag ($r = 0.0049$, *d.f.* = 26, $p = .98$). and none of the multiple regression analyses show any significant effect of word class on the poly-lag variance.

8.4.6.1. Hierarchy 1

The only significant effects to emerge were those related to the target polysyllabic frequency. Although the increase in variance accounted for did not reach significance, the polysyllable frequency was responsible for a significant unique part of the variance which was accounted for ($\beta = -.41$, $p < 0.05$). This whole set of variables accounted for 28% of the poly-lag variance.

8.4.6.2. Hierarchy 2

In this set of hierarchies, the target polysyllable frequency was replaced by the most frequent polysyllable in the cohort. This provided a much greater account of the variance for the aphasic subject. The total amount of variance accounted for is 31%. There were no effects for any monosyllable variables or number of competitor variables. The addition of the highest polysyllable frequency to the equation caused a marginally significant increase in the account of variance accounted for 1% > 31% ($R^2 = .30$ $F(5, 22)$

$= 1.50, p < 0$). Of the variables in this equation contributing to the account of variance, only the highest polysyllable frequency makes a significant unique contribution ($\beta = -0.47, p < 0.02$).

8.4.6.3. Hierarchy 3

When cohort size is used instead of the number of monosyllables, the addition of the target polysyllable frequency variable just fails to reach significance. Target polysyllable frequency did emerge as that responsible for a significant unique amount of the variance which was accounted for ($\beta = -0.44, p < 0.05$). This hierarchy accounted for only 16% of the total variance.

8.4.6.4. Hierarchy 4

When the highest polysyllable frequency replaces the target polysyllable frequency the total amount of variance accounted for is 26%. This is more than the amount accounted for with the inclusion of the target polysyllable frequency but it is less than when number of monosyllables is partialled out with highest polysyllable frequency. The addition of the highest polysyllable frequency does not cause as large an increase in account of variance as when it is partialled out with number of monosyllables but the unique contribution made by the highest polysyllable frequency is slightly raised ($\beta = -0.51, p < 0.01$).

8.4.6.5. Hierarchies 5 and 6

When monosyllable frequency and polysyllable frequency were replaced by the difference between monosyllable and polysyllable frequency, no significant variables emerged as predictors of aphasic poly-lag.[10]

[10]To check that the failure to find significant word class effects is not because the aphasic data sample is smaller than the normal sample, two random subject pairs were chosen from the normal set and their data was analysed alone. It both cases the unique contribution played by the word class variable was marginally significant: pair (a) ($\beta = 0.55, p < 0.056$), and (b) ($\beta = 0.51, p < 0.055$). In addition, the fact that other variables emerged as significant in the aphasic data, corroborates the argument that the use of the regression technique is valid for the sample sizes chosen.

8.4.6.6. Summary of results from the series of hierarchies

In sum, the set of variables which gives the best account of the aphasic's performance is hierarchy 2 - that containing word class, monosyllable frequency, number of monosyllables, cumulative frequency of monosyllables, number of polysyllables and the highest polysyllable frequency. No hierarchy shows any effect of word class or any monosyllable or number of competitor variables. The best predictor of the delay to adoption of polysyllables by the aphasic subject, is the frequency of the highest polysyllable in the cohort.

8.4.6.7. Difference between the aphasic and normal regression analysis results

The regression analyses confirm that the normal performance is strongly affected by the word class of the monosyllable and that the aphasic's is not affected by it. The highest polysyllable in the cohort has an effect on the aphasic poly-lag, whereas the most predictive polysyllable effects for the normal subjects come from the target polysyllable frequency. The normal subjects also show an effect for the number of monosyllable competitors while the aphasic performance is not sensitive to number of competitors.

8.4.7. Aphasic error analysis

The reason why the aphasic subject fails to show a word class effect may be that the closed-class words are not identified. If this hypothesis were correct, then we could claim that A.L. is not be displaying the word class effect because only open-class competitors are activated, even when the target monosyllables are closed-class. To test this hypothesis, I analysed the number of failures to identify the target monosyllable as a function of the word class and frequency of the target polysyllable frequency. A two way ANOVA was used. The identiication rate of the target monosyllable was not affected by the word class of the monosyllable (F (1, 25) = 0.68 p < 1) nor the polysyllable frequency (F (1, 25) = 2.61 p = < 1) nor the interaction of the two (F (1, 25) = 0.18 p = < 1). No condition consistently elicited more correct identification of the target monosyllable by the aphasic than any other. The hypothesis that the aphasic does not show a word class effect because he fails to access the closed-class words can not be upheld.

8.4.8. Normal subject error analysis

Only two polysyllabic words were not guessed by any of the normal subjects - butterscotch, and biography. In both cases the failure to guess the words was due to a failure to access the correct initial cohort; in both cases the initial phoneme was interpreted as /p/. The competing monosyllables were not accessed either. The only other monosyllable not to be elicited was *I* in *idea*. In the two cases in which this occurred, *high* was elicited from the listeners. This low error rate made statistical analysis unfeasible.

8.4.9. Elicited cohorts

The number of elicited responses was recorded as a proportion of words in the actual cohorts. For normal subjects, the size of the elicited polysyllabic cohort was marginally affected by the frequency of the target polysyllable by materials (F (1, 23) = 3.93 p > 0.059). The rare target polysyllables elicited a greater variety of guesses from the normal listeners than did the frequent target polysyllables. I suggest that this reflects the less activated nature of the rare polysyllbles.

There were no effects of target monosyllable class or target polysyllable frequency on the size of elicited cohorts for the aphasic subject. Furthermore, there were no differences between A.L.'s elicited cohorts and the normal elicited cohorts which were explicable in terms of monosyllable word class or polysyllable frequency.

8.4.10. Identification points

A measurement was taken of how long after the emergence of a polysyllabic hypothesis, was the correct polysyllable identified. That is (IP - PP). For the normal subjects the presence of a closed-class monosyllable competitor delayed the identification of the target word (F_1 (1, 24) = , p < 0., F_2 (1, 24) = 4.51 p < 0.05, MinF'(1, 42) = 4.02055, p <.05). The effect of polysyllable frequency was more significant. There was a bigger delay from the poly-point[11] to correctly identifying the polysyllable when it was rare than when it was frequent (F_1 (1, 24) = , p < 0.0, F_2 (1, 24) = 23.62 p < 0.0001,

[11]Point at which the first polysyllabic guess is made.

MinF' (1,42) = 4.0, p <.05). There was no significant interaction. These data indicate that for the normal subjects the relative importance of the polysyllable and monosyllable competitors has reversed. At the point of initial adoption of polysyllable competitors, the most important lexical features were those pertient to the monosyllable contenders(monosyllable word class etc.): later when the measurement reflects commitment to a polysyllabic hypothesis, the influence of the early monosyllable contenders has subsided and polysyllabic competitors are dictating the pattern of recognition. After the initial emergence of polysyllables, the role of the monosyllables diminishes but does not disappear completely. The importance of the target polysyllable frequency is now paramount.

For the aphasic subject the word class of the monosyllable was not significant, (F (1, 24) = 1.33 p < 1). The effect of the polysyllable frequency was significant. The aphasic took longer to identify the rare polysyllables after a polysyllable guess was made, than he did to identify a frequent polysyllable (F (1, 24) = 5.11 p > 0.05). For A.L. the polysyllable frequency is playing a role in determining how quickly the target is identified.

There were no significant differences between the normal and aphasic delays from first emergence of polysyllabic hypothesis and the identification of the target. The effect of polysyllable frequency was not significant (F (1, 24) = 3.31 p > 0.08), nor was the word class of the monosyllable (F (1, 24) = 0.18 p < 1) nor was the interaction between monosyllable class and polysyllable frequency (F (1, 24) = 0.74 p <1).

8.5. Discussion

8.5.1. Normal data

The results from the analyses of variance and the multiple regression analyses converge on the fact that normal subjects show a sensitivity to the word class of early activated (monosyllabic) competitors; listeners maintain the monosyllabic hypothesis longer when the hypothesis corresponds to a closed-class word. These data fit well with the main prediction that closed-class representations receive increased confirmation from functional projections attatched to the lexical entry.

The present findings add weight to Matthei and Kean's (1989) claim that the lack of interference effect from closed-class headed non-words (e.g. **such***erty*) is due to post-access differences between open- and closed-class words rather than earlier stage differences. The current pre-recognition data shows that at this early stage, closed-class words are stronger competitors than comparable open-class words.

In many instances (mainly those in which the monosyllable is open-class and the target polysyllable is frequent) polysyllabic hypotheses are adopted before the objective point of polysyllabicity. This suggests that the longer hypotheses are being sufficiently activated to reach access levels without acoustic ambiguity having been resolved. The onset of polysyllabic acoustic information, however, does facilitate the adoption of polysyllable hypotheses and this process seems to be frequency sensitive -- the normal subjects show an effect of the frequency of the target polysyllable. Listeners are able to integrate the minimal acoustic bottom-up information as it becomes commensurate with a polysyllabic hypothesis. They use this in tandem with lexical level frequency information. This results in frequent polysyllables being accessed more quickly than rare polysyllable targets.

The effect of the number of competitors does not emerge in as straightforward a fashion as might be predicted by interactive models such as TRACE. Only monosyllables appear to be constraining the emergence of polysyllable hypotheses. TRACE would predict that for recognition, the more competitors a target has, the longer it would take to emerge. When the issue is the adoption of a hypothesis (but not necessarily commitment to it hypothesis, as would be the case with recognition), it appears that the effective competitor set is limited to containing mainly monosyllables.

8.5.2. Aphasic data

A.L., a fluent aphasic, does not show sensitivity to the word class of monosyllable competitors. While for the normal subjects, the closed-class hypotheses retain their salience for longer than the open-class monosyllable hypotheses, the aphasic does not distinguish between the two. The present results contradict the findings of Bradley and Garret (1979) which showed that (fluent) Wernicke's aphasics processed closed-class words in the same way that normal subjects did.

His adoption of even monosyllabic candidates is delayed compared to normal. In the majority of cases he retains monosyllable guesses beyond the objective point of polysyllabicity, regardless of the class of the monosyllable. The delay in switching to the intended target polysyllabic hypothesis compared to the normal performance suggests that the rise time of hypotheses is slow and lends some weight to Prather's (1991) claim that slow rise time is the provenance of fluent aphasic processing deficits.

Further, the <u>frequency</u> <u>of</u> <u>the</u> <u>most</u> <u>frequent</u> <u>polysyllable</u> <u>in</u> <u>the</u> <u>cohort</u> is the best predictor of his adoption of a polysyllabic hypothesis. The most frequent polysyllable in the cohort is not always the target polysyllable. A.L.'s processing of the signal is not related to the the target and highest polysyllable in the cohort share much (especially initial) phonetic material - this is the definition of cohort members. Their overlap is not, however, total even at the early stages: prosodic or allophonic variation may distinguish the initial syllable in *numerous* from that of *neutrality*. The normal subjects' adoption of polysyllables is predicted by the frequency of the presented polysyllable. The aphasic's switch to polysyllabic hypotheses is, on the other hand, predicted better by a possible match for the signal but not the match that is actually being presented. Although the current investigation has not quantified the nature of the acoustic cues which the normals appear to integrate, the aphasic does not seem to use them. It is clear that the aphasic is not able to integrate some degree of the incoming acoustic information with lexical information in real time or maintain the complex universe of processing for a large cohort of competitors.

The results concur with the claims made by Kilborn (1991), Bates and MacWhinney, (1989) (1987) and Tyler (1992) that aphasics have difficulty integrating information in real time. Traditional aphasia profiling results (See A.L.'s profile in Table 7.4) show that this subject performs well at the single word level: his ability to retain the final representation of a target word is largely intact. His processing does not match that of normal subjects, however, at the intermediate stage of word recognition. A.L.'s ability to engage with the desired target is shown to be delayed compared with his normal peers.

8.5.3. Summary Conclusions

The normal subjects display a complex system of inter-word competition as part of their resolution of the segmentation problem. Word class, in part, determines the degree of inter-word competition and and strength of positing of word offsets. The fluent aphasic gives no evidence that he is able to use the word class difference as part of his segmentation 'strategy'. Clearly in running speech the closed-class initial competitors can be discarded quicker because of the syntactic level mismatch, but at early stages or pre-recognition processing, word class plays a role in the determination of candidate activation. The aphasic subject fails to integrate this effect into his processing of speech input. For the materials in the present study which all have an embedded monosyllabic competitor, A.L.'s adoption of the polysyllabic hypotheses is most affected by the frequency of the most common polysyllabic candidate.

Chapter 9

Discussion and Conclusions

The work reported in this thesis examined the processes entailed in the lexical segmentation of continuous speech by fluent aphasics and compared their performance on a series of empirical tasks with that of normal ageing listeners. The primary aim was to see which variables in the speech input can be processed by fluent aphasics to facilitate the isolation of discrete words from the continuous speech stream. It was proposed that a proportion of the degradation in understanding spoken language could be ascribed to faulty segmentation processes.

The investigation was composed of a series of 5 experiments which examined the processing of both explicit acoustic and prosodic cues to word juncture and features which affect listeners' segmentation of the speech stream implicitly, through inter-lexical competition of potential word matches.

9.1. Discussion of Empirical Data

9.1.1. The use of explicit cues

Experiment 1 tested fluent aphasics and age matched normal listeners on their ability to use allophonic variation of phonetically identical strings (e.g. *a notion* versus *an ocean*) to assign the word boundaries intended by the speaker. This provided a means of testing whether bottom-up information was of primary importance for the segmentation of ambiguous phrases of this sort, or whether lexical features of the competing hypotheses have a greater influence.

Neither group was able to segment the tokens in accordance with the speaker's intentions with total accuracy. Acoustic differences between the two potential parsings of any given phrase were not perceptually reliable as cues to lexical segmentation. In this respect, the current data add support to the fundamental finding of Nakatani and Dukes (1977) that allophonic variation at word juncture is of limited use to the listener. Further they demonstrates the validity of assigning limited importance to such cues in modelling segmentation. This lends implicit support to models like TRACE (McClelland & Elman, 1986) which allow segmentation to emerge from lexical level competition with little confirmation from the lower processing levels.

Both the aphasic and normal data constitute evidence that lexical level features play a significant role in segmentation of ambiguous speech streams. The datum most relevant to this claim is that both subject groups were more successful at segmentation when the intended segmentation was supported by a frequency bias. Consider the case in which the speech stream gives rise to competing lexical matches which match at the phonetic level (e.g. in /silaɪɪŋ/ *seal* or *see*). Even for the normal listeners, in around 40% of the tokens, the most frequent lexical candidate offered the most attractive hypothesis. For example, given the abovementioned string, regardless of any word boundary allophonic variation the token *see* would receive most confirmation and a segmentation commensurate with this would ensue.

For the normal subjects the fact that segmentation was more successful when acoustic cues and the frequency bias conspired than when they conflicted, adds credence to the notion that the acoustic and lexical information are being used interactively.

The aphasics showed an even larger difference between their successful processing of, on the one hand, materials which were supported by acoustic cues only, and on the other, those whose acoustically supported segmentation was also commensurate with lexical biases -- their segmentation choice was correlated with adherence to the bias-favoured interpretation. This reflects impaired integration of the two different sort of information source. The aphasic results do not, however, reflect consistent segmentation on the basis of frequency driven activation of hypotheses. Instead, the plausibility of the segmented phrases affects the aphasics' response. This demonstrates that a failure to resolve segmentation fully in the normal course of automatic processing, forces the involvement of a metalinguistic component.

In sum, normal processing for segmentation of ambiguous speech streams can not be reliably accomplished with reference to only word boundary allophonic variation. Frequency influences activation of competitor candidates and affects segmentation decisions in ambiguous contexts. The aphasic listener uses metalinguistic strategies invoking plausibility if segmentation is not fully accomplished through frequency influenced activation.

9.1.1.1. Metrical aid to segmentation

Next I tested the claim that sensitivity to the prosodic cues to segmentation would be retained by fluent aphasics. Cutler and Norris (1988) advanced the notion that English speakers use a metrical strategy for the perceptual segmentation of continuous speech. They proposed that the perception of strong syllables by the listener triggers lexical access attempts. When there is no intentional word onset (e.g. at *t* in **min** *tayve*), the presence of a strong syllable will trigger inappropriate lexical access attempts and temporarily hinder the emergence of the intended word whose constituent parts straddle two units.

The current study qualitatively replicated Cutler et al.'s finding; the fluent aphasics failed to detect words embedded in the strong syllable environments more often than in weak syllable environments. This initial finding suggests that fluent aphasics retain a sensitivity to metrical variation and can use it in the process of segmentation. Further analyses imply, however, that the data can be accounted for most fully by invoking a computational account: the variation in detection of the experimental materials previously ascribed to the metrical strength of the environment, can be explained by considering the distribution of biphones at the crucial point of word boundary.

The two analyses can be reconciled when one considers that the biphone data essentially reflect the statistical properties of the lexicon which explain why the metrical pattern of English has an impact on lexical access. I argue that the fluent aphasics show a genuine retention of sensitivity to the statistical probability of phoneme co-occurrence which provides additional facilitation for, but does not rule out the inclusion of, the use of prosodic cues to segmentation.

Activation of hypotheses is also affected by imageability. Words like *mint* in whatever syllabic context, were detected more easily than *act*. This provides a further example of integration of multiple level sources of information in the resolution of segmentation decisions.

The latest instantiations of the Metrical Segmentation Strategy (Norris, 1993b, McQueen et al., 1993) begin to accommodate the current aphasic data. Rather than being an all or nothing trigger, the most recent data offered by Norris et al. support the notion that the MSS acts as a boost to segmentation. They find that when the cohort of competitors activated at the offset of the target word is large, the metrical segmentation strategy boosts lexical access. This more interactive status of the MSS as a feature in a multiple parallel soft constraint satisfaction scenario, is more parsimonious with current interactive models than the previous versions of the theory.

9.1.2. Inter-lexical competition of overlapping hypotheses

The third investigation looked more directly at the inter-word competition effects which had emerged in the initial experiments. I considered how speech is segmented when the speech stream presents more than one overlapping hypothesis (e.g. *trombone bone*. I tested the hypothesis that variation in morphological complexity of the competing hypotheses, as well as orthographic match between the alternative segmentations, would impact on the activation of different contenders and facilitate segmentation in certain cases.

For both the normal and aphasic subjects the prefixed words provided the environment most conducive to the independent analysis of embedded words by the listener. This demonstrates that the morphological complexity of the words is influential in activation of hypotheses. Both the normal and aphasic listeners appear to engage an index of morphological complexity on the activation of a lexical representation which in turn influences the goodness of representation of this competitor. Although aphasics detect embedded candidates within prefixed words more ably than in monomorphemic words, their success at doing this is below normal capacity. For the items which the normal listeners fail to detect, in addition to the prefixed status of the words, frequency contributes to the reason for failure. Frequency of the embedded candidate significantly affected the normal listeners' ability to engage the embedded word and excise it from its context. The role of frequency for the aphasic listeners was more complex and involved relative competitor frequency. In addition, the activation of the embedded word was increased in relation to imageability.

9.1.2.1. On-line processing

Finally, two on-line studies were employed to explore the features involved in entertaining multiple hypotheses with coincident onsets. They considered how a fluent aphasic listener's pre-recognition processing differed from that of his normal peers. The first experiment addressed the issue of frequency which had emerged as an important indicator of performance in the earlier studies. For the normal ageing adults adoption of polysyllabic hypotheses was directly affected by the frequency mediated activation of monosyllable hypotheses with coincident onsets. That is, the adoption of *curious* was affected by the frequency of *cure*. In addition, there was a competitive influence from the number of monosyllable competitors which the polysyllable needed to dominate in order to emerge. No polysyllable effects emerged. The data for the normal subjects failed to support the influence of lateral inhibition.

For the aphasic subject, the monosyllable's competitor strength is not solely governed by the frequency of the monosyllable candidates. Rather, it is constrained by the total number of monosyllable competitors. This means that it is not so important that there is one strong monosyllable stopping the polysyllable rising to recognition, but that there are a number of competing monosyllables. The polysyllables are adopted later by the aphasic than by the normals. The data are most compatible with a notion of 'slow rise' of the polysyllable. The monosyllable responses start later than those of the normal subjects, the longer (polysyllabic) hypotheses take longer to accrue sufficient activation to dominate the monosyllable candidate and any acoustic information is integrated more slowly, which means that its effect on increasing polysyllabic activation is delayed.

The final experiment expanded the consideration of features which are influential in the inter-lexical competition to encompass word class differences. For normal subjects a processing difference between open- and closed-class monosyllables is evident. The data are compatible with the notion that closed-class monosyllables provide greater competition for polysyllable candidates. The activation of polysyllable candidates was also influenced by the number of monosyllables with which it had to compete: multiple activation of short word matches delays the emergence of longer matches. This does not fit easily with the remainder of the data or with the predictions made by either Cohort or TRACE. Instead it suggests that the presence of many competitors, with frequency partialled out, stops a longer candidate accruing sufficient activation for access. This is clearly an area which merits further study.

The aphasic subject shows no sensitivity to word class variation. I speculate that for the normal subjects the closed-class words make better initial competitors because they are able to accrue feedback activation from a syntactic structure onto which closed-class words can project. This would be a parsimonious strategy in running speech because it would provide confirmatory feedback from a quantitatively different level of representation. For the aphasic, the reason for the lack of difference between the open- and closed-class monosyllables in terms of competitor strength, lies in part in their failure to generate the syntactic structure associated with closed-class representations as readily as the normal subjects do.

9.1.3. Activation of competing hypotheses for segmentation by aphasics

The segmentation process in general and the aphasic data generated by the current investigation, in particular are interpretable from the basic perspectives of the Competition Model (Macwhinney and Bates, 1989). The resolution of competition between multiple activated candidates for lexical recognition is achieved through use of explicit cues and through inter-lexical competition in a mechanism which could be characterised by a parallel soft constraint satisfaction model. Such a model would support the assumption that segmentation is accomplished through the integration of many sources of information, converted into a common currency which for normal listeners facilitates the emergence of the speaker's intended segmentation.

Integration of different information relies first on the availability of information to the listener. I have demonstrated that even for normal listeners acoustic cues to word juncture are not 'available' to distinguish between phonetically identical speech input. Acoustic variation at word boundaries is not reliably utilisable. Further, in those instances in which there is limited availability of acoustic cues to normal listeners, fluent aphasics do not use it to facilitate successful segmentation. The availability of the information source has been reduced thus rendering it a less valid cue. This does not necessarily lead to the conclusion that aphasics do not have access to the acoustic cues to segmentation present in the signal or even that they have failed to perceive them; crucially, however it does mean that the cue is not available in the sense that it is not being used at the time when it is required.

9.1.4. Activation and competition in fluent aphasia

In all of the investigations carried out, the fluent aphasics were less able to process the segmentation related information to extract the speaker lexical representations. Let us now consider the role that altered activation of hypotheses plays in this general degradation. The impact which a cue has on lexical processing is mediated through its effect on the competition between the multiple activated candidates for word recognition. The data from this series of experiments has shown that the segmentation problem in fluent aphasia is partially exacerbated by the alteration in activation patterns between lexical matches for the input. The on-line tasks were particularly illuminating in this respect. They showed that the emergence and adoption of lexical targets were delayed in the fluent aphasic compared to the normal listeners. Hyperinhibition, (Berg and Schade, 1992), hypoinhibition (Buckingham et al. 1979, Berg and Schade, 1992) and 'slow-rise time' (Prather et al., 1991) have been invoked to characterise the pattern of lexical competition impairment in aphasic production and perception.

Data from Experiment 4 in which the effect of frequency on adoption of polysyllabic matches for input, failed to provide any evidence for the existence of lateral inhibition in the normal data. There are no normative data on inhibition against which to test the aphasic performance. Bard's (1990) analysis of competition mechanisms provides a suggestion of how to judge the relative validity of the 'slow-rise time' versus hyperinhibition hypotheses. This would entail comparison of aphasic and normal identification of targets with many powerful competitors (which would be a model for inhibition failure) and then normal versus aphasic performance on an item where monosyllable and polysyllable competitors are rare and there are few competitors (which would give a model of slow rise time). Such an investigation on the present results was not possible due to the limited number of data points available which fitted the necessary criteria.

The aphasic data can best be accommodated by the notion of 'slow-rise time' of hypotheses. The 'slow rise' in word hypotheses is manifest the current data in that the target lexical representations do not receive sufficient confirmation in the available time frame. The final experiment demonstrates that in general, polysyllables are slow to rise to access level when faced with competing monosyllable hypotheses. More importantly, however, the hypotheses that do rise, are the most frequent polysyllables which provide a rough match for the input at early time slices (i.e. they are in the word initial cohort). Information which the normal subjects incorporate into their processing to specify a particular polysyllable is integrated into the activation mechanism and attenuates the influence of the frequency supported candidate. The aphasic fails to integrate this valuable bottom-up information with the immediacy shown by the normal listeners. Consequently the monosyllabic hypotheses, which also show slow rise to access level, once activated, retain activational dominance until the most frequency supported candidate accrues sufficient activation to be accessed. Acoustic information is not incorporated into the aphasic's computation of the goodness of lexical representation of competitors.

9.2. Summary Conclusions

Lexical segmentation of continuous speech is compromised in fluent aphasia. Word hypotheses processed by a fluent aphasic do not accrue appropriate activational information from all of the available sources within the time frame in which segmentation problem is normally resolved.

Performance of normal subjects indicate that word boundary related acoustic variation could not normally be considered as a reliably available source to segmentation. Frequency affects the activation of the competing lexical matches for the signal and influences segmentation choice in situations of ambiguity. The frequency of early activated competitors was shown to have great effect on the retention of short word segmentations.

The fluent aphasic performance, although quantitatively impaired compared to normal, reflects an underlying normal competence; their processing seldom displays a totally qualitatively different processing profile to normal. In those cases of occasional failure to adequately resolve segmentation by automatic frequency mediated activation the fluent aphasic invokes the metalinguistic influence of real world plausibility of alternative parses.

The failure of the appropriate candidate to emerge in automatic processing can largely be ascribed to a failure to integrate sources of confirmation for the target representation. The thesis presents evidence that intended segmentations fail to arise because lexical representations commensurate with such segmentation have not integrated the incoming confirmation sufficiently rapidly. In consequence inappropriate competitors retain their activational advantage which in turn makes it more difficult for late integration of information to be effective. The integration problem is thus both affected by, and further exacerbates, the slow rise of target hypotheses.

Activation of competing hypotheses for the establishment of the lexical segmentation is shown to be impaired in fluent aphasia. The direct bearing which this has on word recognition establishes it as an important issue in the study of aphasic speech processing. Most crucially, it has ramifications for models of pathological processing which are severely limited by their neglect of a fundamental processing problem. They do not address that which this thesis has shown to be a non-trivial question; that is, how do aphasics engage with the correct stretch of the speech stream from which to access words and extract meaning from linguistic communication?

Appendix A

Experiment 1: Materials

List A	List B
it swings	its wings
grade a	grey day
a nice man	an iceman
see them eat	see the meat
see lying	seal eyeing
seem able	see Mable
peace talks	pea stalks
play taught	plate ought
tour an	two ran
buy zinc	buys ink
that's tough	that stuff
a name	an aim
lawn chair	launch air
its praise	it sprays
keep sticking	keeps ticking
grasp rice	grass price
an ocean	a notion
make off	may cough
beard rips	beer drips
ice cream	I scream
grey tape	great ape
plump eye	plum pie
why choose	white shoes
I stink	iced ink
we'll own	we loan
youth read	you thread

Appendix B

Experiment 2: Materials

Strong syllable context	Weak syllable context
mintayve	mintef
jumpoov	jumpev
frondoiz	frondes
boltoach	boltesh
diskaipe	diskep
meltook	meltek
huskaze	husken
stumpoaj	stumpej
deskythe	desketh
stampaig	stampeg
blondoiz	blondez
fistoin	fisten
stampaig	stampeg
actuve	actem
fensipe	fensep
loftain	loften
flaskipe	flaskep
joltoach	jolten
wristoin	wrister
duskaze	duskes
softain	softej
spendeek	spendek

Appendix C

Experiment 3: Materials

Prefixed Word / Homophonic Competitor	Prefixed Word / Homographic Competitor
descend/send	report/port
recite/sight	retreat/treat
appeal/peel	reverse/verse
consent/scent	detail/tail
relief/leaf	record/cord
debate/bait	invest/vest
defeat/feet	revolt/volt
receipt/seat	confuse/fuse
regard/guard	decrease/crease
proceeds/seeds	retire/tire
conceal/seal	defence/fence
prepare/pair	confine/fine

Monomorphemic Word/ Homophonic Competitor	Monomorphemic Word/ Homographic Competitor
oblique/leak	terrain/rain
rupee/pea	ordeal/deal
champagne/pain	guitar/tar
settee/tea	trombone/bone
polite/light	rampage/page
cocaine/cane	dispatch/patch
marquee/key	attacks/tacks
parade/raid	divan/van
unite/knight	cravat/vat
ignore/gnaw	amen/men
cadets/debts	parole/role
rely/lie	secure/cure

Appendix D

Experiment 4: Materials

Frequent Monosyllable/ Rare Polysyllable	Rare Monosyllable/ Frequent Polysyllable
pure/puerile	cure/curious
here/hero	peer/period
flat/flatulent	mat/matter
try/trifle	vie/vital
some/sumptuous	come/cumbersome
miss/misnomer	hiss/history
top/topic	prop/proper
skill/skillet	chill/children

Rare Monosyllable/ Rare Polysyllable	Frequent Monosyllable/ Frequent Polysyllable
jig/jigsaw	big /began
chore/chortle	war/water
crone/crony	own/only
claw/chlorine	or/order
pall/paltry	all/also
pew/pupil	few/future
gin/ginger	in/enough
jar/jargon	far/father

Appendix E

Experiment 5: Materials

Closed Class Monosyllable/ Frequent Polysyllable	Open Class Monosyllable/ Frequent Polysyllable
wonder/one	sunday/sun
meeting/me	freedom/free
November/no	location/low
major/may	paper/pay
idea/I	crisis/cry
future/few	newspaper/new
former/for	story/store
minute/my	trial/try

Closed Class Monosyllable/ Rare Polysyllable	Open Class Monosyllable/ Rare Polysyllable
sheepskin/she	scenery/see
hermitage/her	serviceable/sir
biography/by	hypothesis/high
butterscotch/but	cutlery/cut
tupee/to	doodle/do
somersault/some	cumbersome/come
androgenous/and	handicap/hand
household/how	nowadays/now

References

Albert, M.L., & Bear, D. (1974). Time to understand: A case study of word deafness with reference to the role of time in auditory comprehension. *Brain*, *97*, 373-384.

Anderson, J. and Jones, C. (1974). Three theses concerning phonological representations. *Journal of Linguistics*, *10*, 1-26.

Andrews, S. (1989). Frequency and neighbourhood effects on lexical access: Activation or search? *Journal of Experimental Psychology: Human perception and performance.*, *15*, 802-814.

Andrews, S. (1992). Frequency and Neighbourhood Effects on Lexical Access: Lexical Similarity or Orthographic Redundancy. *Journal of Experimental Pscyhology: Learning, Memory and Cognition.*, *18 (2)*, 234-254.

Balota, D. A. and Chumbley J.I. (1985). The locus of word frequency effects in the pronunciation task: Lexical access and/or production? *Journal of Memory and Language.*, *24*, 89-106.

Bard, E.G. (1990). Competition, lateral inihibition, and frequency: comments on the papers of Frauenfelder and Peeters, Marslen-Wilson and others. In Altmann, G. (Ed.), *Cognitive Models of Speech Processing: Psycholinguistic and Computational Perspectives.*. M.I.T. Press.

Bard, E.G. and Shillcock, R.C. (1993). Competitor effects during Lexical Access: Chasing Zipf's tail. In Altmann, G.T. and Shillcock, R.C. (Ed.), *Cognitive models of speech processing: The Sperlonga meeting II.*. LEA.

Bard, E.G., Shillcock, R.C. and Altmann, G.T.M. (1988). The recognition of words after their acoustic offsets in spontaneous speech. Effects of subsequent context. . *Perception and Psychophysics*, *44*, 395-408.

Barry, W.J. (1981). Internal juncture and speech communication. *Arbeitsberichte. Institut fur fonetick. University of KIEL. Germany*, *16*, .

Basso, A., Casati, G. and Vignolo L.A. (1977). Phonemic Idenitifcation Defect if Aphasia. *Cortex*, *13*, 84-95.

Bates, E. and Wulfeck, B. (1989). Comparative aphasiology: A cross-linguistic approach to language breakdown. *Aphasiology*, *3(2)*, 111-142.

Bates, E., McDonald, J. MacWhinney, B. and Applebaum, M. (1991). A Maximum likelihood procedure for the analysis of group and individual data in aphasia research. *Brain and Language*, *40*, 231-265.

Baum, S.R., Daniloff, J.K., Daniloff, R. and Lewis, J. (1982). Sentence comprehension by Broca's aphasics: Effects of some suprasegmental variables. *Brain and Language*, *17*, 261-271.

Behrens, S.J. (1985). The preception of stress and lateralisation of prosody. *Brain and Language*, *26*, 332-348.

Berg, T. and Schade, U. (1992). The role of inhibition in a spreading-activation model of language production. 1. The Psycholinguistic Perspective. *Journal of Psycholinguistic Research*, *21 (6)*, 405-433.

Besner, D. (1983). Deep dyslexia and the right hemisphere hypothesis: Evidence from the U.S.A. and U. S. S. R. *Canadian Journal of Psychology*, *37*, 565 - 571.

Besner, Derek. (1988). Visual word identification: Special-purpose mechanism for the identification of open and closed class items? *Bulletin of the Psychonomic Society*, *26(2)*, 91-93.

Besner, D. and McCann, R. S. (1987). Word frequency pattern and distortion in visual word identification and production. An examination of four classes of models. In Coltheart, M. (Ed.), *Attention and perfromance XII*. Hillsdale.

Blumstein, S. (1981). Perception of Speech in Aphasia: Its Relation to Language . In Myers, Laver and Anderson (Ed.), *The Cognitive Representation of Speech*. North-Holland Publishing Company.

Blumstein, S.E., Cooper, W.E., Zurif, E., and Caramazza, A. (1977b). The Perception and Production of Voice-Onset Time in Aphasia. *Neuropsychologia*, *15*, 371-383.

Blumstein, S.E., and Goodglass, H. (1972). The perception of stress as a semantic cue in aphasia. *Journal of Speech and Hearing Research*, *15*, 800-806.

Blumstein, S., Milberg, W. and Schrier. (1982). Semantic Processing in Aphasia. Evidence from an auditory lexical decision task. *Brain and Language*, *17*, 301-315 .

Blumstein, S.E., Katz, B., Goodglass, H., Shrier, R. & Dworetsky, B. (1985). The Effects of Slowed Speech on Auditory Comprehension in Aphasia. *Brain and Language*, *24*, 246-265.

Blumstein, S.E., Baker, E. and Goodglass, H. (1977a). Phonological Factors in Auditory Comprehension in Aphasia. *Neuropsychologia* , *15*, 19 - 30.

Bond, Z. S. (1971). Units of speech perception. *Ohio State University Working Papers in Linguistics.*, *9*, 1-112.

Bond, Z.S. (1976). On the specification of input units in speech perception. *Brain and Language*, *3*, 72-87.

Bond, Z.S. and Garnes, S. (1980). Misperceptions of Fluent Speech. In Cole, R. (Ed.), *Perception and production of fluent speech*. Erlbaum Associates.

Bradley, D. C. (1978). *Computational distinctions of vocabulary type.*. Doctoral dissertation, .

Bradley, D. C., & Garrett, M. (1979). Effects of vocabulary type in word recognition. Cited in Bradley, Garrett, & Zurif (1980).

Bradley, D. C. & Garrett, M. (1983). Hemisphere differences in the recognition of closed and open class words. *Neuropsychologia*, *21 (2)*, 155-159.

Bradley, D.C., Garrett, M.F. and Zurif, E.B. (1980). Syntactic deficits in Broca's aphasics. In Caplan, D. (Ed.), *Biological studies of mental processes.* . MIT press. Cambs. Mass.

Briscoe, T. (1989). Lexical Access in connected speech recognition. *27th Congress of the Association of computational linguistics., Vancouver, Canada.*, .

Buckingham, H.W., Whitaker, H. & Whitaker, H.A. (1979). Linguistic Perseveration. In Whitaker (Ed.), *Perspectives in neurolinguistics, neuropsychology and pscyholinguistics: A series of mongraphs treatises..* .

Butterfield, S. and Cutler, A. (1988). Segmentation Errors by Human Listeners: Evidence for a Prosodic segmentation strategy . *Proceedings of Speech.* Edinburgh: 7th FASE symposium, Edinburgh, .

Caramazza, A. (1984). The Logic of Neuropsychological Research and the Problem of Patient Classification in Aphasia. *Brain and Language*, *21*, 9-20.

Caramazza, A. (1986). On drawing inferences abourt the structure of normal cognitive systems from the analysis of patterns of impaired performance: The case for single-patient studies. *Brain and Cognition*, *5*, 41-66.

Caramazza, A. (1991). Data, Statistics and Theory: A comment on Bates, McDonald, MacWhinney,and Applebaum's 'A maximum likelihood procudre for the analysis of group and individual data in aphasia research'. *Brain and Language*, *41*, 43-51.

Caramazza, A. and McCloskey, M. (1988). The case for single-patient studies. *Cognitive Neuropsychology*, *5*, 517-528.

Carpenter, R.L., and Rutherford, D.R. (1973). Acoustic Cue Discrimination in Adult Aphasia. *Journal of Speech and Hearing Research*, *16*, 534-544.

Chomsky, N. (1988). *Language and the Problems of Knowledge*. Cambridge, Mass. U.S.A: MIT Press.

Chumbley, J. I. and Balota, D. A. (1984). A words's meaning affects the decision in lexical decision. *Memory and Cognition.*, *12*, 590-606.

Cohen, J. and Cohen, P. (1983). *Applied Multiple Regression and Correlation Analysis for the Behavioural Sciences.*. Hillsdale: Erlbaum.

Cole, R. and Jakimik, J. (1978). Understanding speech: how words are heard. In Underwood, G. (Ed.), *Strategies of Information Processing.*. Academic Press, London. .

Cole, Ronald A. and Jakimik, J. (1980). How are syllables used to recognize words? *Journal of the Acoustical Society of America.*, *67(3)*, 965-970.

Coltheart, M. (1981). The MRC Psycholinguistic database. *Quarterly Journal of Experimental Psychology*, *33 A*, 497-505.

Coltheart, M. (1987b). Functional Architecture of the Language-Processing System. In Coltheart, Sartori and Job. (Ed.), *The cognitive neuropsychology of language*. LEA.

Coltheart, M., Sartori, G., and Job, R. (1987a). *The cognitive neuropsychology of language*. London: LEA.

Connine, C., Blasko, D.G., & Hall, M. (1991). Effects of subsequent sentence context in auditory word recognition: Temporal and Linguistics Constraints. *Journal of Memory and Language*, *30*, 234-250.

Consoli, S. (1973). Performances d'un groupe d'aphasiques un test de descrimination phonemique. *Journale de Psychologie Normal et Pathologique*, *70*, 325-48.

Cooper, F.S., Fant, G., Fourcin, A., Fujimura, O., Scroder, M M.R., & Stevens, K. (1970). Directions for speech research. *IEEE Spectrum*, *5 (3)* , 83.

Cotton, S. and Grosjean, F. (1984). The gating paradigm: A comparison of successive and individual presentation formats. *Perception and Psychophysics*, *35 (1)*, 41-48.

Craig . (1992). Effects of ageing on timed gated isolated word recognition. *Journal of speech and hearing research*, *35 (1)*, 234-238.

Craig, C. and Kim, B.W. (1990). Effects of time gating and word-length on isolated word-recognition performance. *Journal of Speech and Hearing Research.*, *33 (4)*, 808-815.

Cutler, A., Howard, D. and Patterson, K.E. (1989b). Misplaced Stress on Prosody: A reply to Black and Byng. *Cognitive Neuropsychology*, *6*, 67 - 83.

Cutler, A. (1986). Speaking for Listening. In Allport, Mackay, Prinz and Scheerer (Ed.), *Language Perception and Production.* Academic Press.

Cutler, A. (1990). Auditory Lexical Access: Where do we start? In Marslen-Wilson, W. (Ed.), *Lexical Representation and Process.* MIT Press.

Cutler, A. and Butterfield, S. (1989a). Natural speech cues to word segmentation under difficult listening conditions. *Proceedings of EUROSPEECH.* : EUROSPEECH, .

Cutler, A. and Carter, D.M. (1987). The predominance of strong initial syllables in the English vocabulary. *Computer Speech and Language.*, *26*, 133-142.

Cutler, A. and Clifton C.E. (1984). The Use of Prosodic information in Word Recognition. In Bouma, H. and Bouwhmis, D.G . (Ed.), *Attention and Performance X.*. Erlbaum.

Cutler, A. and Norris, D. (1988). The Role of Strong Syllable in Segmentation for Lexical Access. *Journal of Experimental Psychology: Human Perception and Performance, 14*, 113 - 121.

Cutler, A., Mehler, J., Norris, D. and Segui, J. (1983). A Language Specific Comprehension Strategy. *Nature, 304*, 159 - 160.

Cutler, A., Mehler, J., Norris, D. & Segui, J. (1992). The Monolingual Nature of Speech Segmentation by Bilinguals. *Cognitive Psychology, 24 (3)*, 381-410.

Danley, M., and Shapiro, B. (1982). Speech prosody in Broca's aphasia. *Brain and Language, 16*, 171-190.

Danley, M., Cooper, W.E. and Shapiro, B. (1983). Fundamental frequency, language processing, and linguistic structure in Wernicke's aphasia. *Brain and Language, 19*, 1-24.

Diehl, R.L., Kluender, K.R., Foss, D.J., Gernsbacher, M.A. & Parker, E.M. (1985). Consonant identification time depends on the length of the following vowel. Paper presented to the Acoustical Society of America, Austin, Texas.

Edwards, T.J. (1981). Multiple feature analysis of intervocalic English Plosives. *Journal of the Acoustical Society of America, 69(2)*, 535-547.

Elliot L.L., Hammer, M.A. and Evan, K. (1987). Perception of gated, highly familiar spoken monosyllabic nouns by children, teenagers and older adults. *Perception and Pyschophysics, 42(2)*, 150-157.

Ellis, A.W. (1987). Intimations of the modularity or modelarity of mind: Doing Cognitive Neuropsychology. In Coltheart, Sartori and Job (Ed.), *Cognitive Neuropsychology*. Lawrence Erlbaum Associates Ltd.

Emmorey, K.D. (1987). The Neurological substrates for prosodic aspects of speech. *Brain and Language, 30*, 305-320.

Forster K.I. (1976). Accessing the mental lexicon. In Wales, R. J. and Walker, E. W. (Ed.), *New approaches to language mechanisms.*. North-Holland.

Forster, K.I., and Chambers, S.M. (1973). Lexical access and naming time. *Journal of Verbal learning and Verbal behaviour.*, *12*, 627-635.

Francis, W.N. and Kucera, H. (1982). *Frequency analysis of English Usage: Lexicon and Grammar.*. Boston.: Houghton Mifflin.

Franklin, S. (1989). Dissociations in auditory word comprehension; evidence from nine fluent aphasic patients. *Aphaisiology, 3*, 189 - 207.

Frauenfelder, U., Segui, J. and Dijkstra, T. (1990). Lexicon in phoneme monitoring. *Journal of Experimental psychology; human perception and performance, 16*, 77-91.

Frauenfelder, U.H. (1991). Lexical alignment and activation in spoken word recognition. In Sundberg, J., Nord, L., and Carlson, R. (Ed.), *Music, Language, Speech and Brain.*. Wenner-Gren International Symposium Series. .

Frauenfelder, U. (1993). Modelling the time course of spoken-word recognition. *Proceedings of the Conference on the Psychology of Language and Communication Glasgow.*, , .

Frederiksen, J.R., and Kroll J.F. (1976). Spelling and sound: Approaches to the internal lexicon. . *Journal ofExperimental Psychology: Human attention and performance.*, *2*, 361-379.

Friederici, A. & Heeschen, C. (1983). Lexical decisions for inflected open-class items and inflected closed-class words. Paper presented at the Academy of Aphasia Annual Meeting Minneapolis, MN.

Garnham, A. (1985). *Psycholinguistics, Central topics..* London and New York: Routledge, London.

Gaskell, G., and Marslen-Wilson, W. (1993). Match and Mismatch in Phonological Context. *Conference Abstracts: International Conference of the Pscyhology of Language and Communication*, , pp. .

Goodglass, H. and Kaplan, E. (1972). Boston Diagnostic Aphasia Examination. In Goodglass (Ed.), *The Assessment of Aphasia and Realted Disorders.* Lea and Febiger.

Gordon, B. (1983). Lexical access and lexical decision: Mechanisms of frequency sensitivity. *Journal of Memory and Language.*, *24*, 631-645.

Gordon, B. and Caramazza, A. (1982). Lexical dexicion for open- and closed-class items: Failure to replicate differential frequency sensitivity. *Brain and Language.*, *15*, 143-160.

Grainger, J. (1990). Word frequency and neighbourhood frequency effects in lexical decision and naming. *Journal of Memory and Language.*, *29*, 228-244.

Grainger, J., O'Reagan, K., Jacobs, A. and Segui, J. (1989). On the role of competing word units in visual word recognition: The neighbouhood frequency effect. *Perception and Psychophysics*, *45(3)*, 189-195.

Grasser, A. C. & Riha, J. R. (1984). An Application of Multiple Regression Techniques to Sentence Reading Times. In Kieras, David, E. and Just, Marcel, A. (Ed.), *New Methods in Reading Comprehension Research.* L.E.A.

Grosjean, F. (1980). Spoken word-recognition processes and the gating paradigm. *Perception and Psychophysics*, *28*, 267-283.

Grosjean, F. (1980). Linguistic Structures and Performance Structures: Studies in Pause Distribution. In Dechert, H W & Raupack, M (Ed.), *Temporal Variables in Speech.* Mouton, The Hague.

Grosjean, F. (1983). How long is the sentence? Prediction and prosody in the on-line processing of language. *Linguistics*, *21*, 501-529.

Grosjean, F. (1985). The recognition of words after their acoustic offset: Evidence and implications. *Perception and Psychophysics.*, *38*, 299-310.

Halle, M., & Stevens, K. (1957). Speech Recognition - A Model and a Proposal for Research. *IRE transactions of information theory.*, , .

Heeschen, C., Friederici, A., & Drews, E. (1984). Lexical Access in Agrammatism: An inflected language as a testing ground. Paper presented at the Academy of Aphasia Annual Meeting Los Angeles, CA.

Hesketh, A. (1986). Measuring progress in aphasia therapy: a multiple baseline study. *British Journal of Disorders of Communication.*, *21*, 47-62.

Hockett, C. (1958). *A course in Modern Linguistics.* N.Y. U.S.A.: The Macmillan Company.

Howard, D.V., Shaw, R.S., & Heisey, J.G. (1986). Ageing and the time course of semantic activation. *Journal of Gerontology.*, *41*, 195-203.

Jackobson, R. (1970). *Towards a linguistic classification of Aphasic impairment.* : .

Jakimik, J., Cole. R.A., and Rudnicky, A.I. (1985). Sound and spelling in spoken word recognition. *Journal of Memory and Language*, *24*, 165-178.

Jarvella, R.J. and Meijers, G. (1983). Recognising morphemes in spoken words: some evidence for a stem-organised mental lexicon. In Flores D'Arcais, G.B. and Jarvella, R.J. (Ed.), *The process of understanding Language*. Wiley.

Jauhiainen, T. and Nuutila, A. (1977). Auditory Perception of Speech and Speech Sounds in Recent an. *Brain and Language*, *4*, 572-579.

Jusczyk, P. W., Cutler, A. and Redanz, N.J. (1993). Infants' preference for the predominant stress patterns of English words. *Child Development*, *64 (3)*, 675-687.

Kay, J., Lesser, R., and Coltheart, M. (1988). Psycholinguistic Assessments of Language Processing in Aphasia. .

Kertesz, A. (1979). *Aphasia and Associated Disorders: Taxonomy, Localisation and Recovery.*. New York U.S.A.: Grune and Stratton.

Kilborn, Kerry. (1991). Selective Impairment of Grammatical Morphology due to Induced stress in Normal Listeners: Implications for Aphasia. *Brain and Language*, *41*, 275-288.

Kimelman, M.D.Z. (1991). The role of target word stress in auditory comprehension by aphasic listeners. *Journal of Speech and Hearing Research*, *34*, 334-339.

Kimelman, M.D.Z. and McNeil, M.R. (1987). An investigation of emphatic stress comprehension in adult aphasia: A replication. . *Journal of Speech and Hearing Research*, *30*, 295-300.

Kolk, H.H.J. & Grunsven, M. (1981). Nonsyntactic sources of agrammatism. Paper presented at the Academy of Aphasia Annual Meeting London, Ontario.

Ladd, D.R. and Cutler, A. (1983). Introduction. Models and Measurements in the study of prosody. In Cutler, A. and Ladd, D.R. (Ed.), *Prosody: Models and Measurements.*. Springer-Verlag.

Ladefoged, P. (1975). *A Course in Phonetics*. San Diego: Harcourt Brace Jovanovich.

Lahiri, A., & Marslen-Wilson, W.D. (1991). The Mental Representation of Lexical Form: A Phonological Approach to the Recognition Lexicon. *Cognition*, *38*, 245-294.

Lehiste, I. (1960). *An Acoustic-Phonetic Study of Internal Open Juncture*. Basel: Buchdruckerei National-Zeitung.

Lesser, R. (1978). *Linguistic Investigations of Aphasia*. : Blackwell.

Lisker, L., & Abramson, A. (1964). A cross-language study of voicing in initial stops: acoustical measurements. *Word*, *20*, 384-422.

Lisker, L. & Abramson, A. (1967). Some effects of context on voice onset time in English stops. *Language and Speech.*, *10*, 1-28.

Lisker, L., Liberman, AM, Erickson, DM., Dechovit, D. & Mandler, R. (1978). Pushing the VOT Boundary About. *Journal of Speech and Language.*, *20 (Jul)*, 209-216.

Lorch, R.F., Balota, D.A. and Stamm, E.G. (1986). Locus of inhibition effects in the priming of lexical decisions: pre- or post-lexical access? *Memory and Language.*, *14(2)*, .

Luce, P.A. (1986a). A computational analysis of the uniqueness points in auditory word recognition. *Perception and Psychophysics*, *39*, 155-158.

Luce, P.A., Pisoni, D.B. and Goldinger, S.D. (1990). Similarity neighbourhoods of spoken words. In Altmann, G.T. (Ed.), *Cognitive models of speech processing.*. MIT Press.

Luria, A.R. (1970). *Traumatic Aphasia*. The Hague: Mouton.

Macwhinney, B. and Bates, E. (1989). *The crosslinguistic study of sentence processing.*. Cambridge, U.K.: Cambridge University Press.

Marshall, J.C. (1982). What is a Symptom Complex? In Arbib, Caplan and Marshall (Ed.), *Neural Models of Language Processes*. Academic Press.

Marshall, J.C. (1986). The description and interpretation of Aphasic language disorder. *Neuropsychologia, 24(1)*, 5-24.

Marslen-Wilson, W.D. (1984). Function and process in spoken word recognition. In Bouma, H. and Bouwhuis, D. (Ed.), *Attention and Performance X: Control of Language Processes.*. L.E.A.

Marslen-Wilson, W.D. (1987). Functional parallelism in spoken word recognition. *Cognition* , *25*, 71-102.

Marslen-Wilson, W. (1990). Activation, competition and frequency in lexical access. In Altmann, G.T. (Ed.), *Cognitive models of speech processing.*. MIT Press.

Marslen-Wilson, W. (1992). Issues of Process and Representation in Lexical Access. *pre-print*, .

Marslen-Wilson, W.D., & Gaskell, G. (1992). Match and Mismatch in lexical access. *Proceedings of the XXV International Congress of Psychology. Brussels.*, , .

Marslen-Wilson, W. D., and Welsh, A. (1978). Processing interactions and lexical access during word recognition in continuous speech. *Cognitive Psychology, 10* , 29-63.

Marslen-Wilson, W.D., and Zwitserlood, P. (1989). Accessing spoken words: The importance of word onsets. *Journal of Experimental Pscyhology (H), 15 (3)*, 576-585.

Marslen-Wilson, W.D., Brown, C. and Tyler, L.K. (1988). Lexical representation in spoken language comprehension. *Language and Cognitive processes*, *3*, 1-17.

Matthei, E. H. and Kean, M-L. (1989). Postaccess Processes in the Open vs. Closed Class Distinction. *Brain and Language*, *36*, 181-192.

McAllister, J. (). The Processing of Stressed Syllables in Read and Spontaneous speech. Occasional Paper, Dept. of Linguistics, University of Edinburgh.

McClelland, J.L. and Elman, J.L. (1986). The TRACE model of Speech Perception. *Cognitive Psychology, 18*, 1 - 86.

Mclelland, J.L. and Elman, J.L. (1986). The TRACE model of Speech Perception. *Cognitive Psychology, 18*, 1 - 86.

McClelland, J.L. and Rumelhart, D.E. (1985). Distributed memory and the representation of general and specific information. . *Journal of Experimental Psychology; General.*, *114*, 159-188.

McQueen, J. and Cutler, A. (1992). Words within words: Lexical statistics and lexical access. *International conference on spoken language processing.*. Banff, University of Alberta, Canada: University of Alberta, Canada, University of Alberta.

McQueen, J.M., Norris, D., & Cutler, A. (1993). Competition in Spoken Word Recognition: Spotting Words in other Words. *Journal of Experimental Psychology: Learning, Memory and Cognition.*, , .

McRae, K., Jared, D. and Seidenberg, M.S. (1990). On the roles of frequency and lexical access in word naming. *Journal of Memory and Language.*, *29*, 43-65.

McReynolds, L.V. and Kearns, K.P. (1983). *Single-Subject Experimental Designs in Communicative Disorders.*. Baltimore: Baltimore: University Park Press.

Mehler, J. (1981). The role of syllables in speech processing: Infant and adult data. *Philosophical Transactions the Royal Society of London, B295*, 333-352.

Mehler, J., Segui, J. and Frauenfelder, U. (1981). The role of the syllable in language aquisition and perception. In Myers, Laver and Anderson. (Ed.), *The Cognitive Representations of Speech..* .

Milberg, W., Blumstein, S.E., & Dworetzky, B. (1987). Processing of Lexical Ambiguities in Aphasia. *Brain and Language, 31*, .

Milberg, W., Blumstein, S. and Dworetzky, B. (1988). Phonological Processing and Lexical Access in Aphasia. *Brain and Language, 34*, 279-293.

Milberg, W., Blumstein, S.E. and Dworetzky, B. (1988). Phonological factors in semantic facilitation: Evidence from an auditory decision task. *Bulletin of the Psychonomic Society*, , .

Monsell, S. (1985). Repetition and the lexicon. In Ellis, A.W. (Ed.), *Progress in the psychology of language (Vol 2)*.. Erlbaum, London.

Monsell, S., Doyle, M.C. and Haggard, P.N. (1989). Effects of frequency on visual word recognition tasks: Where are they? *Journal of Experimental Psychology: General.*, *118*, 43-71.

Morton, J. (1969). Interaction of information in word recognition. *Psychological Review, 76*, 165-178.

Morton, J. and Patterson, K.E. (1980). A new attempt at an interpretation, or an attempt at a new interpretation. . In Coltheart, M., Patterson, K. and Marshall, J.C. (Ed.), *Deep dyslexia..* Routledge, London.

Moss, H.E., Marslen-Wilson, W.D. & Spence, R. (1989). Perceptual distance and competition in lexical access. *Paper presented and the Experiemental Psychology Society., London*, .

Nakatani, L.H. and Dukes, K.D. (1977). Locus of segmental cues for word juncture. *Journal of the Acoustical Society of America, 62*, 714-719.

Newcombe, F. & Marshall, J. C. (1988). Idealisation meets psychometrics: The case for the right groups and the right individuals. *Cognitive Neuropsychology, 5 (5)*, 549-564.

Nie, N.H., Hull, C.H., Jenkins, J. G., Steinbrenner, K. & \Bent, D.H. (1975). *SPSS: Statistical Package for the social sciences*. New York: McGraw-Hill.

Norris, D. (1993b). SHORTLIST: A hybrid connectionsit model of continuous speech recognition. *Manuscript*, .

Norris, D. and Cutler, A. (1985). Juncture Detection. *Linguistics, 23*, 689 - 705.

Norris, D., Cutler, A., & McQueen, J. (1993a). Competition in spoken word recognition: Spotting words in other words. *Proceedings of the International Conference of the Psychology of Language and Communication, Glasgow*, , .

Otake, T., Hatano, G., Cutler, A. and Mehler, J. (1993). Mora or Syllable - Speech Segmentation in Japanese. *Jouranl of Memory and Language, 32 (2)*, 258-278.

Ottevanger, I. (1983). The detection of mispronunciations and the influence of context. In M.R.P. van den Brocke & A Cohen (Ed.), *Proceddings of the Tenth International Congress of Phonetic Sciences. (Vol IIb*. Dordrecht, The Netherlands.

Paap, K. R., Newsome, S.I., McDonald, J. E., & Schvaneveldt , R. W. (1982). An activation-verification model for letter and word recognition: The word superiority effect. *Psychological Review, 89*, 573-594.

Paap, K.R., McDonald, J.E., Schvanveldt, R.W. and Noel, R.W. . (1987). Frequency and pronunceability in visually presented naming and lexical decision tasks. In Coltheart, M. (Ed.), *Attention and Performance XII*. Erlbaum.

Pashek, G.V. and Brookshire, R.H. . (1982). Effects of rate of speech and linguistic stress on auditory paragraph comprehension of aphasic individuals. *Journal of Speech and Hearing Research*, *25*, 377-383.

Peterson, G. and Lehiste, I. (1960). Duration of syllable nuclei in English. *Journal of the Acoustical Society of America*, *32(6)*, 693.

Petocz, A. and Oliphant, G. (1988). Closed-Class Words as First Syllables Do Interfere with Lexical Decisions for Nonwords: Implications for Theories of Agrammatism. *Brain and Language*, *34*, 127-146.

Picheny, M.A., Durlach, N.I., Braida, L.D. (1986). Speaking Clearly for the Hard of Hearing II:Acoustic Characteristics of Clear and Conversational Speech. *Journal of Speech and Hearing Research*, *29*, 434-446.

Poeck, K. & Pietron, H. (1981). The influence of stretched speech presentation on token test performance of aphasic and right brain damaged patients. *Neuropsychologia*, *19*, 133-136.

Prather, P., & Swinney, D. (1977). *Some effects of syntactic context upon lexical access.*. San Francisco: American Psychological Association.

Prather, P., Shapiro, L., Zurif, E. and Swinney, D. (1991). Real-time examination of lexical processing in aphasics. *Journal of Psycholinguistic Research*, *20 (3)*, 271-281.

Quene, H. and Smits, Y. (1992). On the absence of word segmentation at 'weak' syllables. *International conference on spoken language processsing. Banff.*. Banff, University of Alberta, Canada: University of Alberta, Canada, University of Alberta, Canada.

Quinlan, P.T. (1991). *Connectionism and Psychology*. : .

Ross, E. (1981). The aprosodias: Functional-anatomical organisation of the affective components of language in the right hemisphere. *Archives of Neurology*, *38*, 561-569.

Schriefers, H., Zwitserlood, P. and Roelofs, A. (1991). The identification of Morphologically complex spoken words: Continous processing of decompostions. *Journal of memory and language.*, *30*, 26-47.

Schuell, H.M., Jenkins, J.J. and Landis, L. (1961). Relationship between auditory comprehension and word frequency in aphasia. *Journal of Speech and Hearing Research.*, *4*, 30-36.

Schulhoff, C., and Goodglass, H. . (1969). Dichotic listening, side of brain injury and cerebral dominance. *Neuropsychologia*, *7*, 149-160.

Schulte, E. and Brandt, S.D. (1989). Auditory Verbal comprehension impairment. In Code, C. (Ed.), *The characteristics of Aphasia*. Taylor and Francis, London .

Schwartz, M. (1984). What the classical Aphasia categories can't do for us and why. *Brain and Language*, *21*, 3-8.

Segui, J. and Grainger, J. (1990). Priming word recognition with orthographic neighbours: Effects of relative prime-target frequency. *Journal of Experimental Psychology : Human Perception and Performance.*, *16 (1)*, 65-76.

Segui, J., Mehler, J., Frauenfelder, U. H. and Morton, J. (1982). The word frequency effect and lexical access. *Neuropsychologia*, *20 (6)*, 615-627.

Segui, J., Frauenfelder, U. H., Laine, C. and Mehler, J. (1987). The word frequency effect for open- and closed-class items. . *Cognitive Neuropsychology.*, *4 (1)*, 33-44.

Seidenberg, M. (1989). Reading Complex Words. In Carlson, G. N., Tannenhaus, M. (Ed.), *Linguistic Structure in Language Processing.* Kluwer Academic Publishers.

Seidenberg, M.S. (1989). Visual word recognition and pronunciation: A computational model and its implications. In Marslen-Wilson, W. (Ed.), *Lexical Representation and Process..* .

Seidenberg, M.S. (1989). Visual word recognition and pronunciation: A computational model and its implications. In Marslen-Wilson, W. (Ed.), *Lexical Representation and Process..* .

Shallice, T. (1979). Case-study approach in neupsychological research. *Journal of Clinical Neuropsychology, 1*, 183-211.

Shapiro, Lewis P. & Jensen, Lise R. (1986). Processing Open and Closed Class-Headed Nonwords: Left Hemisphere Support for Separate Vocabularies. *Brain and Language, 28*, 318-327.

Shillcock, R.C. (1990). Lexical Hypotheses in continuous speech. In Altmann, G.T.M. (Ed.), *Cognitive models of speech processes: Psychological and Cognitive perspectives..* MIT Press.

Shillcock, R.C. (Submitted). Competition between Lexical Hypotheses in Auditory Word Recognition. , , .

Shillcock, R.C. & Bard, E.G. (In press). Modularity and the processing of closed class words. In Altmann, G.T.M. and Shillcock, R.C. (Ed.), *Cognitive Models of Speech Processing. Volume Two..* .

Shillcock, R.C. & Lowe, S. (1988). The effects of competition on word recognition. *Work in Progress, 21*, .

Simpson, G.B., & Krueger, M.A. (1991). Selective Access of Homograph Meanings in Sentence Context. *Journal of Memory and Language, 30*, 627-643.

Sparks, R. and Holland, A. (1976). Method: Melodic Intonation Therapy. *Journal of Speech and Hearing Disorders, 41*, 287-297.

Stern, C., Prather, P., Swinney, D., and Zurif, E. (1991). The time course of automatic lexical access and Aging. *Brain and Language, 40*, 359-372.

Stevens, S. & Klatt, D. (1974). Role of formant transitions in the voice-voiceless distinction for stops. *Journal of the Acoustical Society of America, 55*, 653-659.

Svartvik, J., & Quirk, R. (1978). *A Corpus of English conversation..* Lund Sweden: Lund : C.W.K. Gleerup.

Swinney, D.A. (1981). Lexical processing during sentence comprehension; effects of higher order constraints and implications for representation. In Myers, Laver and Anderson. (Ed.), *The cognitve representation of speech.* North Holland.

Swinney, D., & Osterhou, L. (1989). Inference Elaboration during Auditory Discourse Comprehension . *Bulletin of the Psychonomic Society, 27 (6)*, 491.

Tabossi, P. (1993). . In Altmann, G. and Shillcock, R.C. (Ed.), *Cognitive models of speech processing: The 2nd Sperlonga workshop.* LEA.

Taft, L. (1984). *Prosodic constraints and lexical parsing strategies..* Doctoral dissertation, University of Massachusetts.

Taft, M. & Forster, K. (1976). Lexical Storage and Retrieval of Polymorphemic and Polysyllabic Words. *Journal of Verbal Learning and Verbal Behaviour, 15*, 607-620.

Taft, M. and Forster, K.I. (1975). Lexical storage and retrieval of prefixed words. *Journal of verbal learning and verbal behaviour, 38A*, 351-366.

Tallal, P. and Piercy, M. (1975). Developmental Aphasia: the perception of brief vowels and extended consonants. *Neuropsychologia*, *13*, 69-74.

Tannenhaus, M.K., Leiman, J.M. & Seidenberg, M.S. (1979). Evidence for multiple stages in the processing of ambiguous words in syntactic contexts. *Journal of Verbal Learning and Verbal Behaviour*, *18*, 427-440.

Tucker, D., Watson, R. and Heilman, K. (1977). Discrimination and evocation of affectively intoned speech in patients with right parietal disease. *Neurology*, *27*, 947-950.

Tyler, L. K. (1984). The structure of the initial cohort: Evidence from gating. *Perception and Psychophysics*, *36 (5)*, 417-427.

Tyler, L.K. (1985). Real-time comprehension in agrammatism : A case study. *Brain and Language*, *26*, 259-275.

Tyler, L.K. (1988). Spoken language comprehension in a Fluent Aphasic patient. *Cognitive Neuropsychology*, *5(3)*, 375-400.

Tyler, L.K. (1992). *Spoken Language Comprehension.* : LEA.

Tyler, L.K. and Wessels. (1983). Is Gating an Online task? Evidence from Naming Latency data. *Perception and Psychophysics*, *38*, 217-222.

Tyler, L.K., Behrens, S., Cobb, H. and Marslen-Wilson, W. (1990). Processing distinctions between stems and affixes: Evidence from a non-fluent aphasic patient. *Cognition*, *36*, 129-153.

Tyler, L.K., Marseln-Wilson, Rentoul, J.and Hanney, P. (1988b). Continuous and Discontinuous Access in Spoken Word Recgonition: The role of derivational prefixes. *Journal of memory and language*, *27*, 368-381.

Van Lancker, D. and Fromkin, V.A. (1973). Hemispheric specialization for pitch and 'tone': Evidence from Thai. *Journal of Phonetics*, *1*, 101-111.

Varney, N. (1984). Phonemic Imperception in Aphasia. *Brain and Language*, *21*, 85-94.

Wayland, S.C., Wingfield, A. and Goodglass, H. (1989). Recognition of isolated words: The dynamics of cohort reduction. *Applied Psycholinguistics*, *10*, 475-487.

Weintraub, S., Mesulam, M., and Kramer, L. (1981). Disturbances in prosody: A right hemisphere contribution of language. *Archieves of Neurology*, *38*, 742-744.

Whaley, C. P. (1978). Word-nonword classification time. *Journal of Verbal learning and Verbal Behaviour.*, *143-154*, 143-154.

Whitaker, H.A. and Slotnick, H.B. (1988). Comments on 'The case for single patient studies': Is NeuroPsychology Possible? *Cognitive Neuropsychology.*, *5(5)*, 529-533.

Willmes, K. (1990). Statistical methods for a single-case study approach to aphasia therapy research. *Aphasiology*, *4*, 415-436.

Zipf, G.K. (1935). *The Psycho-biology of Language: an Introduction to Dynamic Philology..* Boston.: Houghton-Mifflin.

Zue, V. (1976). Some perceptual experiments on the Mandarin tones. *Journal of the Acoustical Society of America*, *60*, 545.

Zurif, E., Swinney, D. and Fodor, J.A. (1991). An evaluation of assumptions underlying the single-patient-only position in neuropsycholol gical research: a reply. *Brain and Cognition*, *16*, 198-210.

Zwitserlood P. (1989). The locus of the effects of sentential-semantic context in spoken-word recognition. *Cognition*, *32*, 25-64.